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NATIONAL COMMUNICATIONS SYSTEM
TECHNICAL INFORMATION BULLETIN

CHARACTERIZATION OF ABOVE-BASELINE PHYSICAL THREATS TO TELECOMMUNICATIONS LINKS

NOVEMBER 1997

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EXECUTIVE SUMMARY

This report provides a characterization of above baseline physical threats to telecommunication links of public telecommunication networks (PTNs). These above baseline physical threats may lead to stresses that can affect the telecommunication links but which are not ordinarily protected against by telecommunications providers. The report will provide information for providers and users of telecommunications links to help in developing, where required, measures against above baseline physical threats.

This report has been prepared in response to a Standards Committee T1 - Telecommunications project to develop new national standards, "Protection of Telecommunications Links from Physical Stress and Radiation Effects." This report forms the technical basis and rationale for the above baseline classification standard.

The above baseline physical stresses characterized in this report include the following:

—Vibration
—Liquid penetration in optical fiber cables
—Radiation
—Temperature
—Wind and ice
—Construction threats
—Corrosion of above-ground links
—Corrosion of below-ground links
—Lightning and exposure to ac power
—Telecommunications power

CHARACTERIZATION OF ABOVE-BASELINE PHYSICAL THREATS TO TELECOMMUNICATIONS LINKS

TECHNICAL REPORT

1.0 INTRODUCTION

1.1 Purpose of This Report

The purpose of this report is to characterize above baseline physical threats to telecommunications links that exceed those stresses defined in ANSI T1.328-1995, *American National Standard for Telecommunications--Protection of Telecommunications Links from Physical Stress and Radiation Effects and Associated Requirements for DC Power Systems (A Baseline Standard)*.[1] This report has been prepared in response to a Standards Committee T1 - Telecommunications, Standard Project Proposal, approved as Project T1Y1-27.[2] The characterization of these above baseline threats is intended to provide information about the physical stresses that can affect telecommunications links but which are not ordinarily protected against by telecommunications service providers. Ordinary threats are considered baseline, while the stresses in this report are considered above baseline.

1.2 Policy Statement - NCS Mission

Presidential Executive Order 12472 defines the mission of the National Communications System (NCS), in part, as the coordination of the planning for, and provision of, National Security Emergency Preparedness (NSEP) communication for the Federal Government under all circumstances, including crises or emergency. Key responsibilities of the NCS are: (1) to seek development of a national telecommunications infrastructure that is survivable, responsive to NSEP needs of the President and the Federal Government, capable of satisfying priority telecommunications, and consistent with other national policies; (2) to serve as a focal point for joint Industry-Government National Coordinating Center. This report supports the national security telecommunications policy as stated in NSDD-97, "…the national telecommunications infrastructure must possess the functional characteristics of connectivity, redundancy, interoperability, restorability, and hardness necessary to provide a range of telecommunication services to support essential national leadership requirements."

1.3 Scope of This Report

1.3.1 Covered telecommunication plant

The above baseline physical threats characterized in this report apply to the telecommunications links that interconnect environmentally controlled centers of PTNs, see Figure 1.1. The links are fiber-optic or copper-conductor cables of trunk, feeder, and local distribution plant. The links include connection and repeater points that are on pedestals or poles, or in manholes, and that are not environmentally controlled. The termination of the links in environmentally controlled buildings, and their power sources, are included, but the buildings themselves and their contents are excluded. This report is concerned primarily with the generic features of telecommunications links rather than with specific network equipment or components.

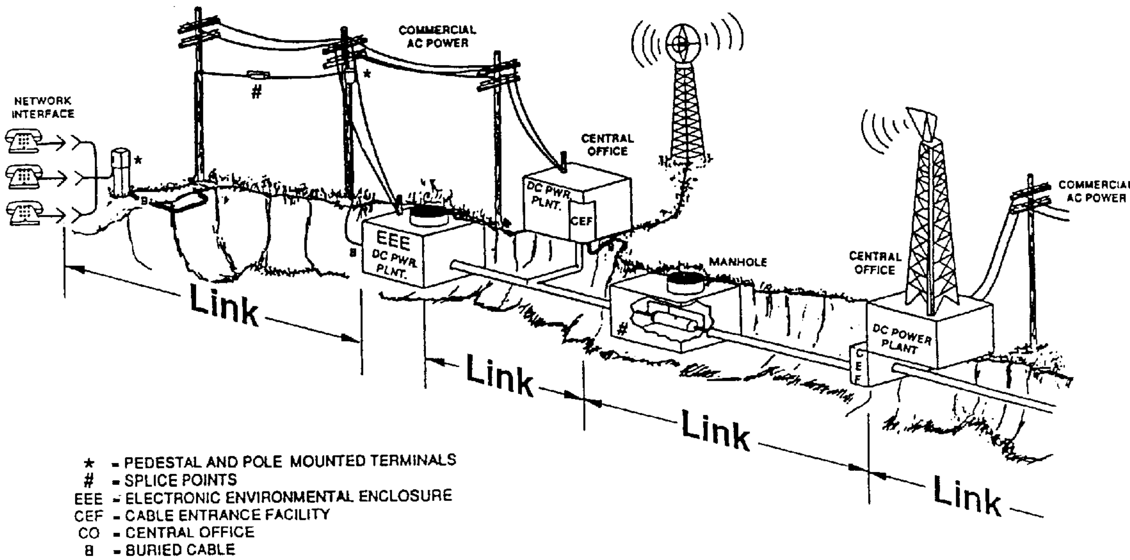

Figure 1.1. Telecommunication Links in the Network

1.3.2 Covered physical stresses

The above baseline physical stresses characterized in this report include the following:

— Vibration

— Liquid penetration in optical fiber cables

— Radiation

— Temperature

— Wind and ice

— Construction threats

— Corrosion of above-ground links

— Corrosion of below-ground links

— Lightning and exposure to ac power

— Telecommunications power

1.3.3 Application

This report discusses above baseline physical threats only, and does not provide mitigative measures against the resultant stresses. Such measures depend on specific stresses and must be developed on a case-by-case basis. Because these are above baseline threats, the stresses, application and methodology to mitigate against them must be negotiated with each individual carrier as the potential for the stresses are identified. The basis for application and methodology will depend on the service requesters' needs for economical mitigation, as they (the service requesters) will be responsible for costs in excess of baseline mitigation measures.[2]

The stresses characterized here are beyond those described in ANSI T1.328-1995. The stresses, however, may occur, but not in all locations. How and when they occur depends on geography, natural forces, and man-made forces. The nature of these above baseline threats is unpredictable. As such, they can only be characterized in terms of probabilities or be based on worst-case historical occurrence. The above baseline threats in this report are believed to be at the upper limit of reasonable probability, but have some chance of being exceeded in extraordinary circumstances. Threats from terrorism and war are not considered.

1.4 Organization of This Report

Physical stresses are briefly discussed in this chapter to provide background information. In subsequent chapters, the physical threats are defined in further detail along with supporting calculations and references.

1.5 Definitions

Baseline standard - A standard intended to establish foundation level protection from damage due to physical stress and radiation under typical geographic and local environmental conditions. This type of standard establishes generally accepted practices to meet the needs of public telecommunications networks.

Above baseline standard - A classification standard that sets forth various levels of physical stress and radiation, over and above the typical levels addressed by the baseline standards. The application of above baseline standards to specific telecommunication links must be negotiated with each individual carrier: LEC, IC, etc., by the service requester on a case by case basis.

1.6 Description of Threats

The stresses covered in this report are both natural and man-made. Threats from terrorism and acts of war are not covered.

An overview of physical stresses on fiber optic long-distance networks has been made available as a multitier specification by the NCS.[3] That overview is augmented by this report, which also considers physical stresses to copper-conductor cable links. It includes stresses to fiber optic links that are not emphasized in the multitier specification, but which telecommunications providers have found to be significant. Stresses that are considered to be ordinary, that is, covered by the baseline standard, are not covered here.

This report characterizes above baseline physical threats in terms of upper and lower limits. The lower limits are ordinarily threats covered in the baseline standard. The threats create stresses which may be protected against in some areas, but not as a general practice throughout the United States.

1.7 Vibration

The above baseline vibration threat may arise from unusually severe seismic shocks arising from construction or blasting activity in close proximity to one or more elements of a telecommunications link. The above baseline earthquake threat is defined by greater threat or risk levels than anticipated by the baseline standard. The baseline levels are predicated on a risk of 90% probability of not being exceeded within 50 years. The above baseline levels are associated with published intensity and frequency of occurrence data.

1.8 Liquid Penetration in Optical Fiber Cables

Threats from liquid penetration in optical fiber cables are divided into two categories: water, and other aqueous solutions. The threat from water has been well documented. An above baseline threat level is water at high temperatures, such as cables in the presence of steam. For other aqueous liquids, the threat is the presence of chemicals such as ammonia (NH_4OH) or other household cleaners (chlorine bleach, for example), as well as petroleum products (gasoline, kerosene, etc.), which are expected to be more destructive than water.

1.9 Radiation

1.9.1 Effects on optical fiber cables

The baseline document indicates the concerns relative to solar radiation, primarily that of the degradation of the polymer coatings. The above baseline threat from other radiations, for example, gamma radiation from nuclear power sources, will have a profound effect on the optical properties of the fiber.

1.9.2 Electromagnetic interference

Electromagnetic emissions from high-power radio transmitters, portable transmitters, and nearby electronic equipment may cause Electromagnetic Interference (EMI) to electronic equipment in telecommunications links. The effects of EMI range from audible noise on the link (e.g., audio rectification in a partially operated surge protector) to shutting down high-capacity service (e.g., many bit errors in an optical repeater).

Another EMI threat to telecommunications links is caused by broadband electromagnetic sources, such as electric motors, combustion engines, and electrostatic discharges. These sources generate broadband emissions because of the impulsive nature of the signals.

1.10 Temperature

The above baseline temperature threat is fires either external or internal to the links structure, from man-made or natural sources. Above baseline external fires have heat release rates in excess of 10 megawatts. For example, forest fires, flammable liquid fires from fuel spills or vehicular crashes, flammable gas fires from pipeline breaks or railroad tanker cars, or fires in adjacent structures are all potentially above baseline threats to telecommunication links.

Above baseline fires internal to the links structure have heat release rates of approximately 50 to 100 kilowatts in the area of origin. For example, an above baseline fire is a self-sustaining fire in the cables in a cable entrance facility.

1.11 Wind and Ice

Baseline levels of wind and ice stresses are well established in the National Electrical Safety Code. [4] Above baseline winds include those from severe storms such as hurricanes or tornadoes, with wind speeds in excess of 110 miles per hour. Above baseline ice loading is 0.5 inches of radial ice on aerial links structures.

1.12 Construction

Dig-ups pose the greatest above baseline threat to telecommunications links. These events occur during all types of construction endeavors involving digging, plowing, or drilling activities. The resultant damage is to underground and buried elements of the links, namely copper and fiber cables, and, to a lesser extent, manholes and other underground structures.

1.13 Corrosion of Above-ground Links

Corrosion poses threats to above-ground telecommunications links either through chemical or galvanic action. Conditions under which above baseline threats from corrosion exist are temperatures outside the baseline range of 4°C to 65°C, condensation and ice buildup, the presence of voltages above the baseline of 48 volts dc, and exposure to NO_2, Cl_2, and hygroscopic dust.

1.14 Corrosion of Below-ground Links

Above baseline threats to below-ground links structures consist of dc stray currents (from railroads, gas and power lines, and welding), chemical corrosion (water, fuels, sewage intrusion), low resistance soil conditions, incorrect grounding and bonding connections, bacterial corrosion, and galvanic corrosion. Conditions under which above baseline threats occur are the presence of voltages above the baseline of 48 volts, the presence of gasoline or other fuels, or low resistance soil.

1.15 Lightning and Exposure to AC Power

Power faults and lightning strokes to telecommunication links can have local and system-wide effects. Local effects include mechanical and thermal damage to the cable at the point of strike or a fault. System-wide effects include coupled or conducted voltages and currents that can propagate along the cables and impinge on components of the link.

1.16 Loss of Telecommunications Power

The above baseline threat from loss of telecommunications power is commercial power outages that extend beyond three hours.

1.17 References

1. ANSI T1.328-1995, *American National Standard for Telecommunications--Protection of Telecommunications Links from Physical Stress and Radiation Effects and Associated Requirements for DC Power Systems (A Baseline Standard)*.

   Information about ANSI is available on the World Wide Web at http://www.ansi.org.

   Another source of information about the telecommunications industry can be found at the Telecommunications Industry Association's web site at http://www.industry.net/c/orgindex.tia.

2. *Protection of Telecommunications Links from Physical Stress and Radiation Effects*, Standards Committee T1, Telecommunications Standard Project Proposal T1 LB 273

Revised January 16, 1992.

3. NCS Technical Information Bulletin 87-25, *Multitier Specification for NSEP Enhancement of Fiber Optic Long-Distance Telecommunication Networks*.

4. ANSI C2-1993, *National Electrical Safety Code*, Institute of Electrical and Electronic Engineers, Piscataway, NJ.

2.0 VIBRATION THREATS

2.1 Above Baseline Characterizations

2.1.1 Vibration threat

This section discusses the proposed above baseline threat to telecommunications links from vibrations and earthquakes. The baseline standard for vibrations and earthquakes is presented in ANSI T1.328-1995.[1] The technical rationale for the baseline standard is contained in the National Communications System, Technical Information Bulletin 93-9, *Protection of Telecommunication Links from Physical Stress*,[2] which preceded the development and publication of T1.328. The postulated above baseline threat increases the intensity of the baseline threats and includes additional threat types not included in the baseline standard (T1.328). The rationale for these changes is also included in this report.

Baseline standards presented in [1] and [3] discuss the physical threat to telecommunications links from typical vibration sources including train and vehicular traffic, rotating machinery and construction activities. Telecommunications links are generally capable of resisting the physical threat based upon the strength derived from their installed configurations that relate directly to the mounting and fastening of component equipment and interconnecting cables within facilities. Examples of typical mounting conditions include cables secured to racks in manholes and CEVs, maintaining safe working loads on support hardware and fastening equipment to structural walls, floors or ceilings. In baseline installations, no special fastening or bracing is required to provide the level of robustness for the vibration resistance of links.

The measures described in the baseline standard suggest that telecommunications link components be tested or analyzed to meet peak acceleration levels of 0.1 g (g is the acceleration due to gravity) to provide a level of vibration resistance commensurate with the levels of resistance of equipment in central offices (often an integral part of the facility associated with cable entrance facilities).

A proposed above baseline standard would suggest that telecommunication links be resistant to exposure from potentially higher levels of transient vibration or shock. The most extreme condition could be considered the exposure of the links to shocks caused by demolition or blasting at close proximity less than 50 ft. The seismic waves produced from the ignition of such nearby explosive charges contain energy occupying a broad frequency spectrum. These waves travel through the ground and may excite structures including cable links and their supporting structures. Levels are typically presented as peak particle velocities measured in units of inches/second.

As such, it is proposed that the above baseline threat be adopted from the accepted levels of exposure for building structures to transient vibrations. The current level for building structures is considered to be 2.0 inches/second at any distance based upon data from actual events. For continuous vibration sources, the above baseline threats use 0.1 g peak for single dominant frequency link elements (e.g., cables) and 0.5 g for broad frequency link elements (repeater housings) to provide commensurate levels with the network elements contained in buildings (central offices).

2.1.1.1 Transient vibration

For transient vibrations to links elements, the threat level is 2.0 in/sec peak velocity within the range from 1 to 500 Hz.

For connectors, the transient vibration threat is 30 g's peak acceleration from a half sine pulse.

2.1.1.2 Continuous vibration

For vibrations with broad frequency content (not containing a single dominate frequency), the displacement is 0.01 inches (0.3 mm) peak-to-peak, with acceleration of 0.5 g zero-to-peak. For vibrations with a single dominant frequency, the single frequency acceleration is 0.1 g zero-to-peak.

For connectors, the continuous vibration threat is a displacement 0.06 inches (1.5 mm) peak-to-peak and acceleration of 9 g zero-to-peak.

2.1.2 Earthquake threat

The earthquake intensities discussed in the referenced standards were developed from previously recorded earthquake events. The severity levels coincide with recent zoning changes dictated by Uniform Building Codes.[4] This baseline was based upon establishing peak ground motion acceleration levels having a 90% probability of not being exceeded in 50 years. The risk levels are depicted in five zones numbered zero through four. The high risk areas along the San Andreas fault are considered to be the most severe and have been designated as Zone 4. The zones are defined in a map within the referenced documents.[10][11]

It is proposed that the level for the above baseline earthquake threat use greater threat or risk levels associated with published intensity and frequency of occurrence data. The proposal would be to incorporate the latest United States Geological Survey (USGS)[5][6][7][8][9] data, for ground motions, with an **elevated** earthquake risk, i.e., a 95% probability, of not being exceeded within 50 years. The proposed above-baseline earthquake zones are to include an earthquake risk represented by an earthquake zoning map, Figure 2.1, revised to show the peak accelerations anticipated from the elevated risk levels. The revised map would be based upon the map contained in the referenced documents.[10][11] It is noted that the peak ground accelerations from the USGS data indicate a peak ground acceleration of 1.7 g for Zone 4, which is consistent with the current levels of intensity specified by ANSI T1.329 and Bellcore NEBS of 1.6 g as peak acceleration levels.[10][11] The peak levels are suggested as above baseline since the levels considered the amplified effects of the building structure from the earthquake ground motions and may exceed the baseline earthquake resistance for links. In some cases, this level of intensity is consistent with the baseline standards set forth by those current users of the ANSI and Bellcore documents for network equipment. It is however considered above baseline for link elements that are typically not designed for upper building floor acceleration levels.

2.1.2.1 Zones

The Earthquake Zoning Map, Figure 2.1, has been developed by Bellcore through microzonation techniques based on frequency-of-occurrence information, as well as the magnitude and intensity history of earthquakes that have occurred in each region noted. The severities have been updated to coincide with the recent zoning changes dictated by Uniform Building Codes. This map is intended to represent the current estimate of earthquake zoning for telecommunication facilities located in the United States. This zoning map presents a simplified earthquake risk expressed as peak ground acceleration.

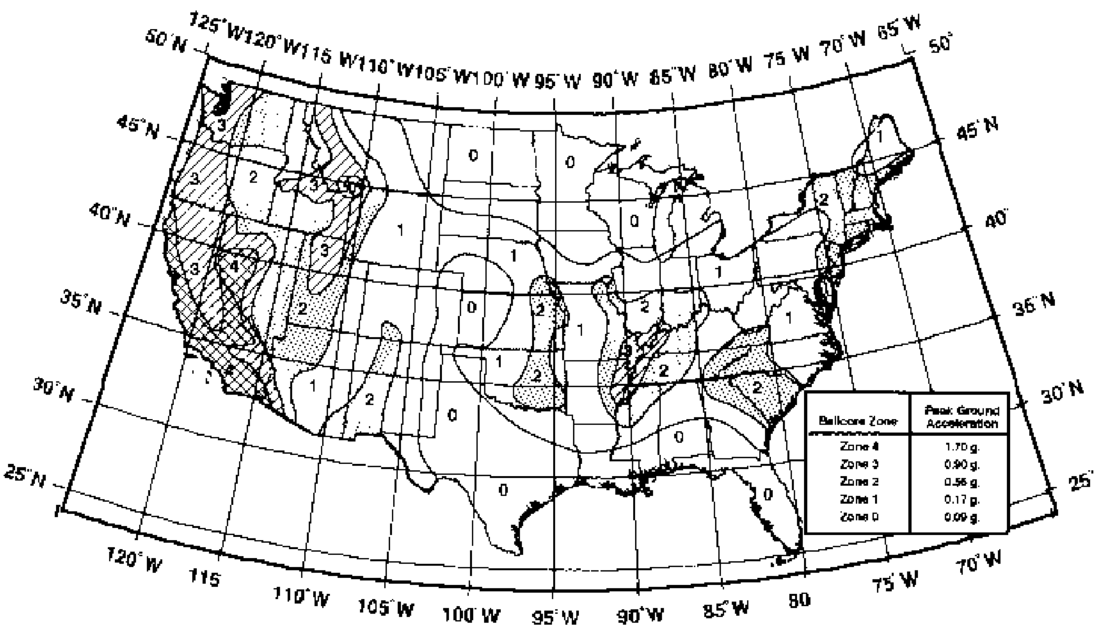

Figure 2.1. Above Baseline Earthquake Zones

2.1.2.2 Intensity

The intensities listed by Zone are derived from the latest U.S. Geological Survey data (as of August 1997), for ground motions, with an earthquake risk with a 95% chance of not being exceeded within 50 years. The peak ground acceleration value was found within each Bellcore Zone. That peak value was then used as the peak ground acceleration for the entire Zone.

For the most current and detailed peak ground acceleration and response spectra data, refer to the USGS information.[9]

2.2 Rationale

2.2.1 Vibration

Vibration sources can produce a wide band of frequencies from 1 to over 500 Hz. The most common and most damaging are vibrations of 100 Hz and lower, since the lower mechanical resonant frequencies of buildings, structures and the equipment, and the majority of vibration energy is in this range.

Motions resulting from ground vibration may cause damage to telecommunications links, including below-ground and above-ground structures and enclosures for repeaters or connections, and the cable links (either copper or fiber) between the offices and enclosures. Some sources of vibration are construction operations, including blasting from demolition, pile drivers, pavement breakers, bulldozers, and wrecking balls. Some other possible sources are blasting from mining, trains or heavy vehicular traffic, manufacturing equipment (such as forges and presses) rotating or pulsating machinery, and earthquakes.

2.2.1.1 Types of vibration

Vibratory motions may be either continuous or transient. Continuous vibrations are generally associated with rotating machinery. The highest amplitudes generally result from energy buildup at the natural mechanical frequency of the equipment. Transient vibrations are generally characterized by random motions produced over short durations, usually less than 2 to 3 minutes. One example of transient vibrations is vibration caused by blasting, which generally builds quickly to peak amplitudes; another is earthquakes. Transient vibrations decay to negligible values over a brief time.

2.2.1.2 Effects of vibration on structures and links equipment

The possible effects of vibrations on telecommunications links (including cabling and terminations) can be severe if the vibration source is strong and continuous. Continuous vibrations may cause structures to significantly amplify the vibrations, if the vibration frequency and natural resonant frequency of the structure are sufficiently similar. Also, fatigue-induced degradation or failure is likely to occur for this same reason. Transient vibrations, because of their short duration, normally do not initiate large resonant amplification effects.

The factors that most strongly influence the vibration response of structures are:

— Intensity and duration of the vibration
— Distance between the vibration source and the structure
— Sensitivity of the structure or equipment to the vibration source
— Location of equipment within a structure. (For example, more severe vibrations are generally experienced at the center of a floor span.)
— Proximity in the frequency domain between the natural or resonant frequencies of the composite structure and the vibration source frequencies

Vibration-induced effects may also be amplified by energy cross-coupling. As an example, vertical vibrations of a floor or structure may induce horizontal vibrations of increased amplitude at the top of a tall, slender equipment framework.

Typical consequences of vibration on the physical integrity of structures and equipment and cables they contain are listed below.

<u>Links structures</u>

— Cracks develop in walls and floors.
— Soil settles under floors, removing bearing support for structures that have slab-on-grade construction.

<u>Links elements other than cables</u>

— Circuit cards become dislodged from their holders.
— Fretting corrosion of connectors can develop, causing data errors.
— Surface-mounted components on circuit cards lose bond strength.
— Solder joints fatigue or crack.
— Heavy subcomponents (transformers, capacitors, etc.) become loose.
— Mechanical parts degrade.
— Motors become unbalanced.
— Hard drive or tape drive errors could occur.
— Relays can be forced open or closed.

<u>Cables</u>

— Cables may become abraded from rubbing on cable racks or structure walls.
— Cable terminations may suffer fatigue failure.

2.2.1.3 Rationale for vibration threats

The baseline threat listed in ANSI T1.328-1995 for vibration is 0.1 g from 5 to 200 Hz. This threat is representative of continuous vibrations, with a single dominant frequency. The above baseline threat includes this continuous vibration threat, and incorporates the threat of continuous vibrations of broad frequency content. Continuous vibrations with broad frequency content are typical of multiple continuous sources with different frequency content.

The above baseline threat also lists a continuous and transient threat for connectors. This threat has been taken from industry accepted Bellcore and EIA connector vibration requirements.

The above baseline threat includes a superimposed transient vibration threat. The vibration threat of mining blasting, construction blasting, and explosive demolition are currently limited by Federal law to 2 in/sec, above 30 Hz, at the foundation of homes, public buildings, etc.[12] This law does not directly apply to links structures, or to other types of transient vibration threats. Since the upper bound limit of potential blast vibrations is not known, and low frequencies tend to cause more damage, a 2 in/sec peak particle velocity at any distance from the link elements was chosen as the above baseline threat. This threat corresponds to the lower bound of commercial building cosmetic damage caused by blasting. Several examples of distances between links structures and a vibration source at the proposed vibration limit are shown in Table 2.1, below.

Source of Data	Vibration Source	Approximate Distance to Produce 2.0 in./sec.
Reference 13	1 lb. Dynamite Embedded in Ground	50 ft.
Reference 13	36000 ft.-lb. Diesel Pile Driver	22 ft.
Reference 13	Vibratory Pile Driver	12 ft.
Reference 13	Pavement Breaker, 6 ft. Drop Height	9 ft.
Reference 13	2 Ton Wrecking Ball, 40 ft. Drop Height	6 ft.
Reference 13	Trucks / Caisson Drilling / Large Bulldozers	3 ft.
Reference 13	Jackhammer	2 ft.
Reference 14	14 Story Building Explosive Demolition	72 ft.
Reference 14	2.2 lb. Dynamite	30 ft.
Reference 14	35000 ft.-lb. Drop Hammer on Clay	13 ft.
Reference 14	30000 ft.-lb. Diesel Pile Driver	8 ft.
Reference 14	Bulldozer	2 ft.
Bellcore	Three Level Parking Garage Explosive Demolition	30 ft.

Table 2.1. Distances to Vibration Sources for 2.0 in./sec. Velocities

Note that this data is only representative information. Several inconsistent results can be seen that are caused by the unique conditions of a site, the coupling between the ground and the vibration source, and the coupling between the ground and a vibration receiver. For instance the 1 lb. dynamite from [13] requires a separation distance of 50 ft. to not exceed 2 in./sec., while the 2.2 lb. dynamite from [14] requires a separation 30 ft.

2.2.2 Earthquakes

The response of telecommunications links to transient earthquake ground motions depends on the characteristics of the links and the intensity of the ground motion. Soil characteristics tend to further amplify ground-motion effects. Soils consisting of water-saturated sand, loose clays, or mud generally tend to amplify the low-frequency, high-displacement effects. Soils composed of hard rock tend to amplify the high-frequency, high-acceleration effects. In either case, the levels of response of telecommunication plant may be further amplified by the ground motions and resulting soil conditions, and structural resonance if the natural frequency of the link is within the energy bandwidth of a strong-motion earthquake.

Ground motions during an earthquake are transient vibrations that usually last from 10 to 60 seconds, but may last longer. A typical strong-motion earthquake acceleration consists of 2 to 5 seconds of initial buildup, 8 to 10 seconds of strong shaking, and a gradual decay that lasts from 20 to 45 (or more) seconds. The predominant frequency of typical strong-motion earthquakes generally ranges from 1 to 20 Hz, although lower frequencies may occur on soft soil sites. Structures that have natural mechanical frequencies in this range are more responsive, and susceptible, to earthquake excitations than those with frequencies outside this range.

Attenuation of the intensity of shaking with distance from the epicenter depends a great deal on the geology, the source mechanism, and the magnitude. In general, an epicenter peak ground acceleration of 0.8 g can decrease to approximately 0.2 g 60 miles away, and 0.1 g 80 miles away for certain soils in California. However, soils in areas east of the Rocky Mountains tend to be less dissipative, and strong seismic waves can propagate considerably farther in such areas. A typical earthquake acceleration-time history waveform having a peak 1.6 g acceleration is shown in Figure 2.2, below.

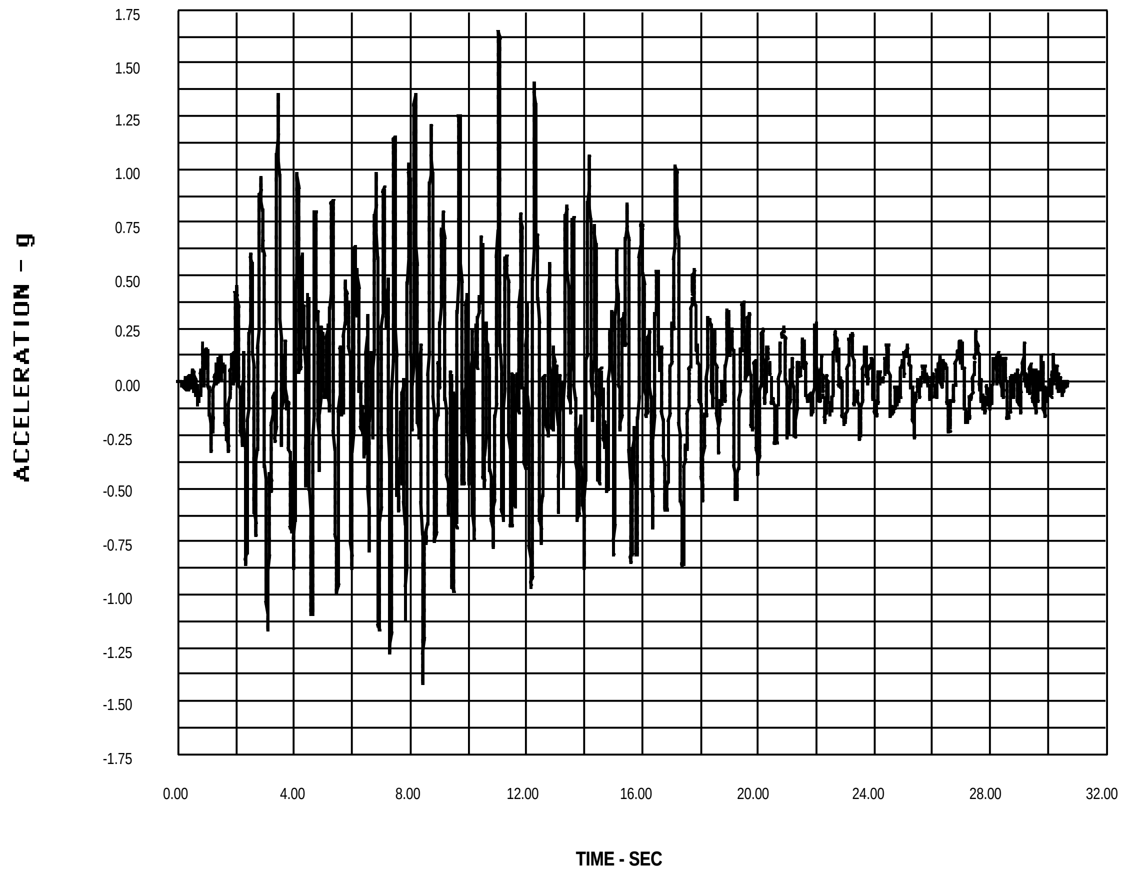

Figure 2.2. Earthquake Waveform

2.2.2.1 Strong-motion earthquakes: geographic regions and frequency of occurrence

The Earthquake Zoning Map contained in NEBS GR-63-CORE has been developed by Bellcore through microzonation techniques based on frequency-of-occurrence information, as well as the magnitude and intensity history of earthquakes that have occurred in each region noted. The severities have been updated to parallel with the recent zoning changes dictated by Uniform Building Codes. This map, see Figure 2.1, is intended to represent the current estimate of earthquake zoning for telecommunication facilities located in the United States.

This zoning map presents a simplified earthquake risk expressed as peak ground acceleration. The intensities listed by Zone are derived from the latest U.S. Geological Survey data (as of August 1997), for ground motions, with an earthquake risk with a 95% chance of not being exceeded within 50 years.

2.2.2.2 Effects of earthquakes on telecommunications links

Telecommunication plant must be protected from possibly damaging stresses caused by earthquake-induced forces. Above-ground structures that house telecommunications equipment must be capable of resisting the potential earthquake loads and minimizing the effects of acceleration on the equipment. Links may be damaged if they are not properly secured, or if displacements cause them to repeatedly collide with structural elements or other equipment.

Below-ground structures may be damaged during earthquakes as a result of liquefaction (solid ground becoming liquid from shaking) in areas of loose, water saturated soils. Floating or in sinking may result from the presence or absence of buoyancy effects on a given structure in liquefied soils. Shear failures at a cable entrance to an enclosure may result from vertical displacement of the enclosure if sufficient slack is not provided in the cable.

Cables may be damaged if ground motions cause buckling or kinking, especially if minimum bend radii are not observed. Fiber-optic cables, because of their glass construction, may be susceptible to damage in high-risk areas if protection such as armor or innerduct is not provided.

Microwave towers and telephone poles may be susceptible to damage during earthquakes because of their tall slender structure and their low natural vibration frequency. The towers often tend to rock during earthquake excitations: this places higher stresses on connection hardware and guy-wire supports. Rocking frequencies associated with microwave towers are generally within the strong-motion frequencies of earthquakes.

2.2.2.3 Rationale for above baseline earthquake threats

Typically, earthquake threats are selected as an earthquake risk with a 90% chance of not being exceeded within 50 years. The USGS 95% level is proposed as the above baseline threat that suggests a peak ground acceleration of 1.7 g. To further substantiate the above baseline threat, the levels specified in ANSI standards are presented. ANSI-T1.329 is intended for earthquake threats to equipment within a building, with a 90% chance of not being exceeded within 50 years. The standard provides levels for buildings that include amplified earthquake accelerations from the ground. The levels specified by ANSI are conservative for most links elements which are only exposed to ground vibrations. The peak accelerations from T1.329 are 1.6 g for the high-risk-level and 0.64 g for the low-risk-level. The high-risk-level corresponds to Bellcore and ANSI Zones 3 and 4, and the low-risk-level corresponds to Bellcore and ANSI Zones 0, 1 and 2.

The proposed above baseline earthquake threat is based upon U.S. Geological Survey data as of August 1997, for ground motions, with an earthquake risk with a 95% chance of not being exceeded within 50 years. The peak ground acceleration values from the USGS data have been found within each Bellcore Zone.

Zone	*Bellcore/ANSI (90%) levels*	*USGS (95%) levels*
4	1.60 g	1.70 g
3	1.00 g	0.90 g
2	0.65 g	0.57 g
1	0.60 g	0.17 g
0	0.60 g	0.09 g

Table 2.2. Comparison of Bellcore and USGS Earthquake Levels

This above baseline threat derived from the USGS data compares favorably with the T1.329 criteria for the Zone 4 earthquake risk areas. The USGS levels are slightly higher than ANSI (1.7 g vs. 1.6 g). The Low risk zones 0, 1 and 2 of USGS also compare favorably with the ANSI levels, having a peak ground acceleration of 0.57 g, slightly below the ANSI level of 0.65 g. It is suggested that the USGS levels be used for low risk areas where site specific information is available. If site specific information is not available, the more conservative levels specified in ANSI should be considered.

2.3 References

1. ANSI T1.328-1995, *American National Standard for Telecommunications--Protection of Telecommunications Links from Physical Stress and Radiation Effects and Associated Requirements for DC Power Systems (A Baseline Standard).*

2. Technical Information Bulletin 93-9, *Protection of Telecommunication Links from Physical Stress,* National Communications System.

3. National Communications Systems (NCS TIB 87-24) and National Telecommunications and Information Administration (NTIA Report 87-226), *Multitier Specification for NSEP Enhancement of Fiber Optic Long-Distance Telecommunication Networks,* December 1987.

4. Uniform Building Code 1994 Edition.

5. National Communication System (NCS), August 30, 1993, *Natural and Technological Disaster Threats to National Security and Emergency Preparedness (NS/EP) Telecommunications* [SOW 3.4.9].

6. Department of the Interior, U.S. Geological Survey, *National Seismic Hazard Maps, June 1996 Documentation*, July 19, 1996.

7. Department of the Interior, U.S. Geological Survey, *National Seismic Hazard Maps, June 1996*.

8. Department of the Interior, U.S. Geological Survey, *USGS Spectral Response Maps and Their Relationship with Seismic Design Forces in Building Codes*, Open-File Report 95-596, 1996.

9. Geological Survey
MS 966, Box 25046
Denver Federal Center
Denver, CO 80225.

Telephone and E-mail for these maps are (303) 273-8556 and afrankel@gldesg.cr.usgs.gov.
These data can also be accessed directly via the USGS web page at: "http://geohazards.cr.usgs.gov/eq/index.html"

10. ANSI T1.329-1995, *American National Standard for Telecommunications--Network equipment--Earthquake resistance*.

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3.0 THREATS OF LIQUID PENETRATION IN OPTICAL FIBER CABLES

3.1 Above Baseline Characterizations

3.1.1 Water

It has been well documented that the concentration (or more precisely the thermodynamic activity) of liquid water or water vapor on the surface of silica (light guide) fibers is the critical agent controlling their mechanical degradation with or without stress. Studies of such degradation over normal ranges of temperature (25°C to 100°C) and concentration (liquid water to water vapor at 1 atmosphere of pressure) have shown that at a given water concentration, the temperature dependence is well-behaved and is controlled by the energy necessary for the water to break the silicon-oxygen bond (~80 kJ/m). Thus, the behavior in this temperature and pressure range is predictable. On the other hand, almost no work has been done when these critical parameters are outside this range. A single report from Bellcore gives some data and indicates that steam is extremely aggressive, but an understanding of the process is lacking.

3.1.2 Aqueous solutions

Very little detailed work has been done on other aqueous liquids which are expected to be more aggressive than water, e.g., ammonia (NH_4OH) or other household cleaners (chlorine bleach), as well as petroleum products (gasoline, kerosene, etc.). Again, some work from Bellcore has addressed this issue and shown that in some cases extreme degradation can occur, especially with ammonia, but more work needs to be done to understand the processes involved.

3.2 Rationale

3.2.1 Water

Possibly the most critical environment for accelerating optical fiber fatigue to be considered here is that of superheated water, i.e., steam. This aggressive environment is quite often encountered in below street-level urban situations and may also be encountered in other industrial situations such as power plant applications. The onset of molecular water penetration through conventional cable material is essentially instantaneous and far-reaching into the cable core. Specifically designed cables that offer resistance to water migration to the fiber/glass interface must be used for these applications.

3.2.2 Aqueous solutions

Very often aggressive environments such as household cleaners (ammonia or bleach) or petroleum products are encountered. It is known that ammonia is among the most aggressive of these environments. Strength degradation before polymer degradation, and severe strength degradation and polymer degradation are observed after prolonged exposure. To date, only the use of hermetic carbon coatings has been shown to resist ammonia attack.

3.3 References

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2. Biswas, Kurkjian and Gebizlioglu, “Reliability of Optical Fibers in Steam and Petrochemical Environments”, IWCS, 1996, pg 456-463.

3. Biswas and Kurkjian, “Hermetic Coated Fibers- How Robust Are They?”, IWCS 1995.

4. Kurkjian and Matthewson, “Room Temperature Strength Degradation of Light guide Fibers,” El.Letts., 1996.

4.0 THREATS OF RADIATION EFFECTS

4.1 Above Baseline Characterizations

4.1.1 Gamma radiation

The baseline document indicates the concerns relative to solar radiation, primarily that of the degradation of the polymer coatings. Other radiations, e.g., nuclear will have a profound effect on the optical properties of the fiber, but no known effect on the mechanical properties. The above baseline level of gamma radiation is 10^6 Gy (100 Gy is 1 rad).

4.1.2 Electromagnetic interference

Electromagnetic emissions from high-power radio transmitters, portable transmitters, and nearby electronic equipment may cause Electromagnetic Interference (EMI) to electronic equipment in telecommunications links (e.g., multiplexers, repeaters, optical network units). Examples of high-power transmitters are AM broadcast, television, FM broadcast, and radar. The effects of EMI range from audible noise on the link (e.g., audio rectification in an operated surge protector) to shutting down high-capacity service (e.g., many bit errors in an optical repeater).

Another EMI threat to telecommunications links is caused by broadband electromagnetic sources. Examples of broadband sources are; electric motors, combustion engines, and electrostatic discharges. These sources generate broadband emissions because of the impulsive nature of the signals.

4.1.2.1 Narrowband electric field immunity

Narrowband electric field sources are those with radiating frequencies between 10 kHz and 10 GHz. These fields include a mixture of emissions from licensed transmitters (e.g., AM and FM broadcast, television, amateur radio, and police/emergency communications).

The maximum permissible transmission power for new AM broadcast stations is 50 kW; for FM broadcast stations, 100 kW; and for TV broadcast stations and commercial radar, 5 MW [1]. The maximum permissible transmission power for private short wave stations is 50 kW. It should be noted that these values are the input power to the antenna and not the Effective Radiated Power (ERP) in the main beam of the antenna. The ERP can be larger because it includes the antenna gain.

The increased usage of portable transmitters (e.g., cellular telephone, VHF business band, and Personal Communication Services [PCS]) is also a threat to the telecommunication links. Although these are low-power transmitters, the electromagnetic fields close to one of these transmitters are considerable, since field magnitude is inversely proportional to the square of the distance.

ANSI C63.12 [2] recommends that general-purpose electronics have at least a 1 V/m immunity capability but also states that for reliable operation at all locations the level should be higher. Equipment in telecommunication links can be providing services of a critical nature, and therefore can be expected to have a higher level of immunity.

Collocated ancillary electronic equipment may be a source of EMI to electronic telecommunications link equipment. This ancillary equipment may be located within one meter in front or back of the telecommunications link, or worse, adjacent to the link.

The increased density of electronic equipment (nonintentional radiators) near telecommunications links and intentional radiators (e.g., broadcast radio stations) in the vicinity of telecommunications links augment the electromagnetic field strength incident on telecommunications links.

The electromagnetic waves generated by the above-mentioned sources can cause EMI to electronic telecommunication link equipment (e.g., digital/optical repeaters, optical network units, multiplexers/demultiplexers). The interference may range from audible noise (broadcast demodulation) on voiceband leads to shutting down of repeaters. Audio demodulation may occur at operated carbon block protectors in the telecommunication links. A T1 repeater may be completely incapacitated by EMI that causes it to receive, or perceive to receive, excessive bit errors in a short period of time.

Electromagnetic interference to telecommunications links is important to the Public Switched Telecommunication Network (PSTN) users since it can render the PSTN unusable. Therefore, above baseline immunity standards are necessary for the electronic equipment in the telecommunications link to reduce the possibility of radio interference from intentional sources (e.g., licensed transmitters) and non-intentional sources (e.g., collocated electronic equipment).

4.1.2.2 Broadband field immunity

Examples of sources of broadband interference include combustion engines, electric motors, faulty power line insulators, and electrostatic discharges. Electrostatic Discharges (ESDs) are considered broadband events with energy distributed in the frequency range 10 MHZ to 10 GHz. Broadband interference generated by sparking typically has most of its emissions centered between 400 and 500 MHZ.

It is important that electronic equipment in telecommunication links have an above baseline level of immunity to such sources because of the uncontrolled environment of its operation. Repeaters for digital carrier systems commonly are located at the base of a wooden pole, in a pedestal, or in a busy commercial or residential area, where they may be exposed to broadband interference from nearby power tools, gasoline engines, or electrostatic discharges. Such broadband interference can have a large effect on digital equipment, since a spark (a broadband signal source) can be interpreted by the digital equipment as the leading edge of a bit.

4.2 Rationale

4.2.1 Gamma radiation

It is known that all glasses are subject to increases in optical loss due to the action of gamma radiation. Baseline conditions were considered to be that of gamma doses from solar radiation. Above baseline may include any level of gamma radiation up to that due to a nuclear power plant, say 106 Gy. Such situations may include the use of the fiber in, or in the vicinity of, a nuclear reactor, or a storage facility, for instance for nuclear waste. Recent results with ‘modern’ fibers have been positive. It has been suggested that fibers may be found which are capable of withstanding essentially any level of gamma radiation without excessive optical or mechanical degradation, at least in the moderate lengths (i.e., 50 meters). In cases where longer lengths of fiber are required, the induced optical losses may become a problem. In all cases, however, induced loss behavior must be determined. In some cases, degradation of the polymer coating is encountered, and in these cases while optical performance may not be affected, apparent mechanical degradation is experienced because of the reduced mechanical protection afforded by the coating. If no coating degradation is experienced, slight strength increases have been observed.

4.2.2 Electromagnetic interference

4.2.2.1 Narrowband EMI sources

The increased density of electronic equipment (nonintentional radiators) near telecommunications links and intentional radiators (e.g., broadcast radio stations, cellular telephones, handy talkies, PCS, etc.) in the vicinity of telecommunications links augment the electromagnetic field strength incident on telecommunications links. The electromagnetic waves generated by these sources can cause Electromagnetic Interference (EMI) to electronic telecommunication link equipment (e.g., digital/optical repeaters, optical network units, multiplexers/demultiplexers). The interference may range from audible noise (broadcast demodulation) on voiceband leads to shutting down of repeaters. The nature of the installations of equipment in links (e.g., on poles or in pedestals) makes them particularly subject to interference from a wide range of EMI sources.

Electromagnetic interference to telecommunication links is important because it can render the networks unusable. Therefore, above baseline immunity standards are necessary for the electronic equipment in the telecommunication links to reduce the possibility of radio interference from intentional sources (e.g., licensed transmitters) and non-intentional sources (e.g., collocated electronic equipment).

The immunity limits of this standard do not provide assurance of noninterference. The levels are specified based on ambient electric fields that may be present in telecommunication link sites that are exposed to strong fields from an intentional radiator. In particular, field strengths greater than the values shown in Figure 4.1 (which will be referred to as the 3.1 volts per meter [V/m], peak on the modulated carrier, criterion) for electric fields may be present at some sites, and the 15.3 V/m limit, peak on the modulated carrier, is intended to accommodate those cases. If ambient field strengths exceed the 15.3 V/m limit, additional shielding of the structure that houses the telecommunication link equipment may be needed.

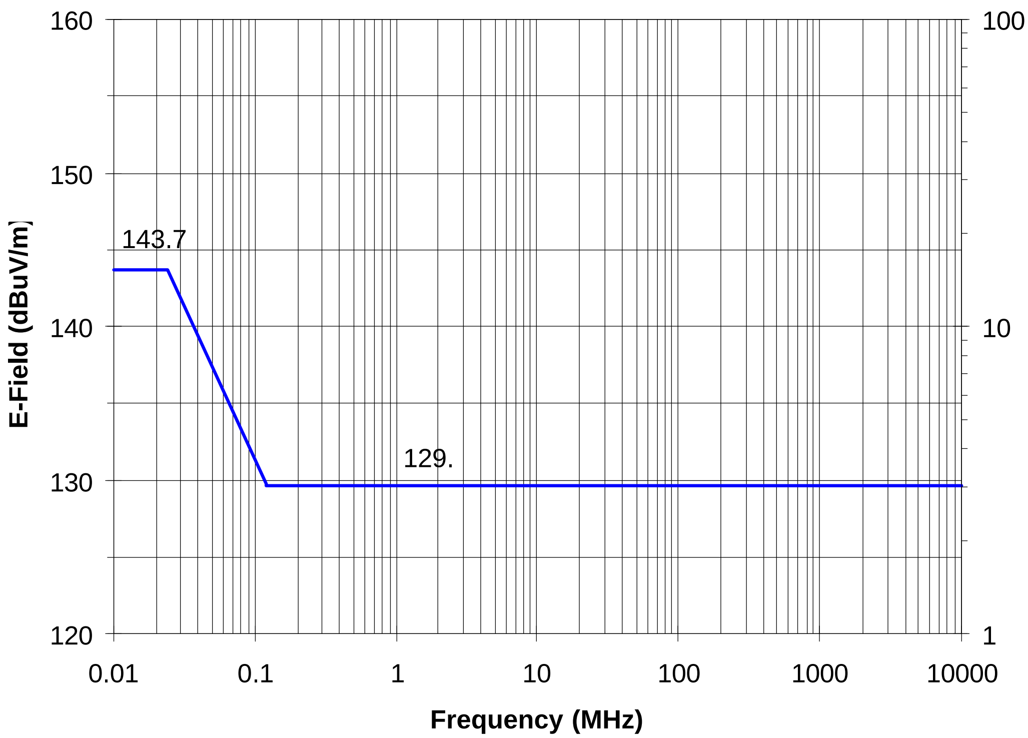

Figure 4.1. Radiated Immunity

<u>Intentional Sources</u>

Licensed radio services are the main source of electromagnetic signals that originate outside of telecommunication link buildings. Emissions from licensed transmitters are mostly narrowband.

Figure 4.2 is a plot of the 15.3 V/m (143.7 dB V/m) radiated immunity criteria, the 3.1 V/m (129.8 dB V/m) radiated immunity criteria (bottom line), and frequency bands where licensed radio services operate. The radio services shown do not include all licensed services in the frequency range of the figure. Electronic telecommunication link equipment should withstand the 15.3 V/m limit if they are to be installed in a high ambient field that is produced by those services.

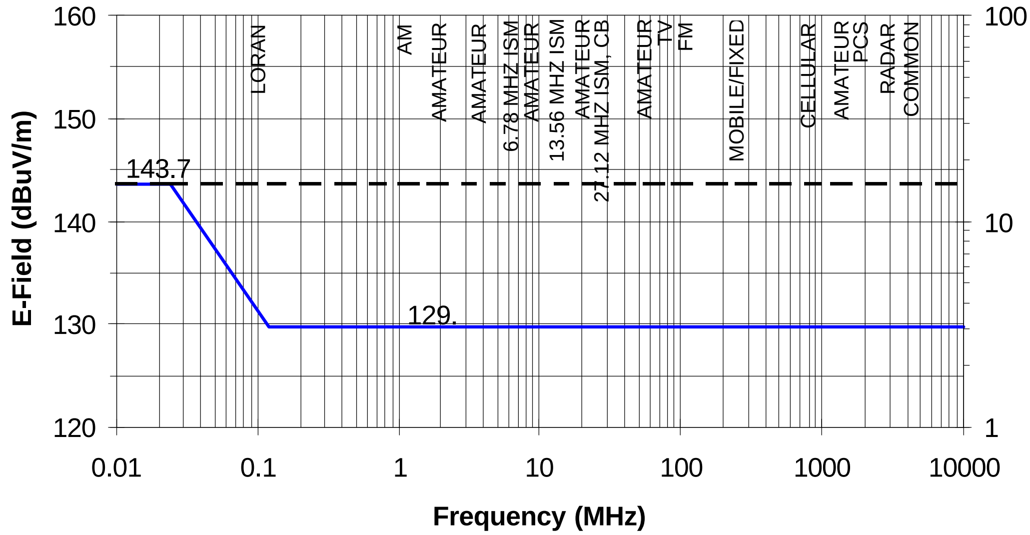

Figure 4.2. Radiated Immunity - Intentional Sources

Whereas Figure 4.2 shows the frequency ranges of radio services, it does not suggest the signal levels commonly found at telecommunication link sites. A determinant of the field strength of RF signals from outside telecommunication link sites is the distance to the transmitting antenna. Figures 4.3, 4.4, and 4.5 show the relationship between the power of an RF source (transmitting antenna) and the separation distance from the RF source to the telecommunication link site to obtain a particular electric-field strength (Section 4.2.2.3 describes the equations to generate Figures 4.3, 4.4, and 4.5). The regions to the right of the curves represent combinations of distance and power that generate electric fields less than the curve legend. The curves represent the 15.3 V/m and 3.1 V/m limits for radiated immunity. Regions to the left of the curve represent distance and power combinations that exceed the electric-field immunity limit. For example, equipment that meets the radiated immunity 3.1 V/m limit at 1 MHZ (middle of AM broadcast band) may be located 0.7 km from a 50 kW AM broadcast station antenna (see Figure 4.3). If the equipment meets the radiated immunity 15.3 V/m limit at 1 MHZ, it could be located 140 meters from the same antenna.

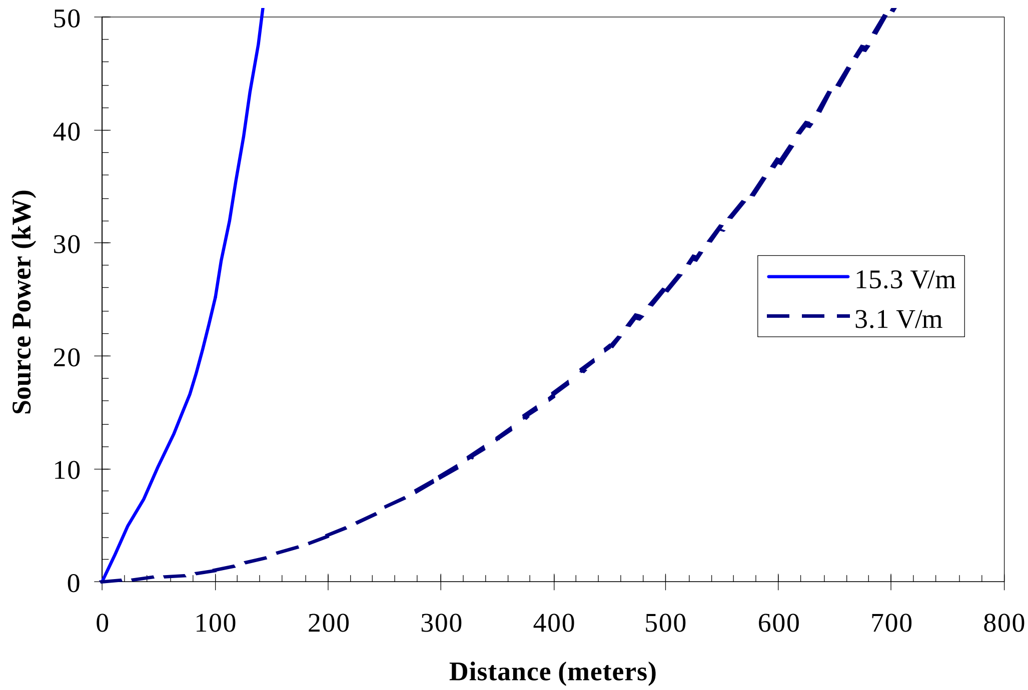

Figure 4.3. Relationship of RF Source Power and Distance From Source, AM Stations

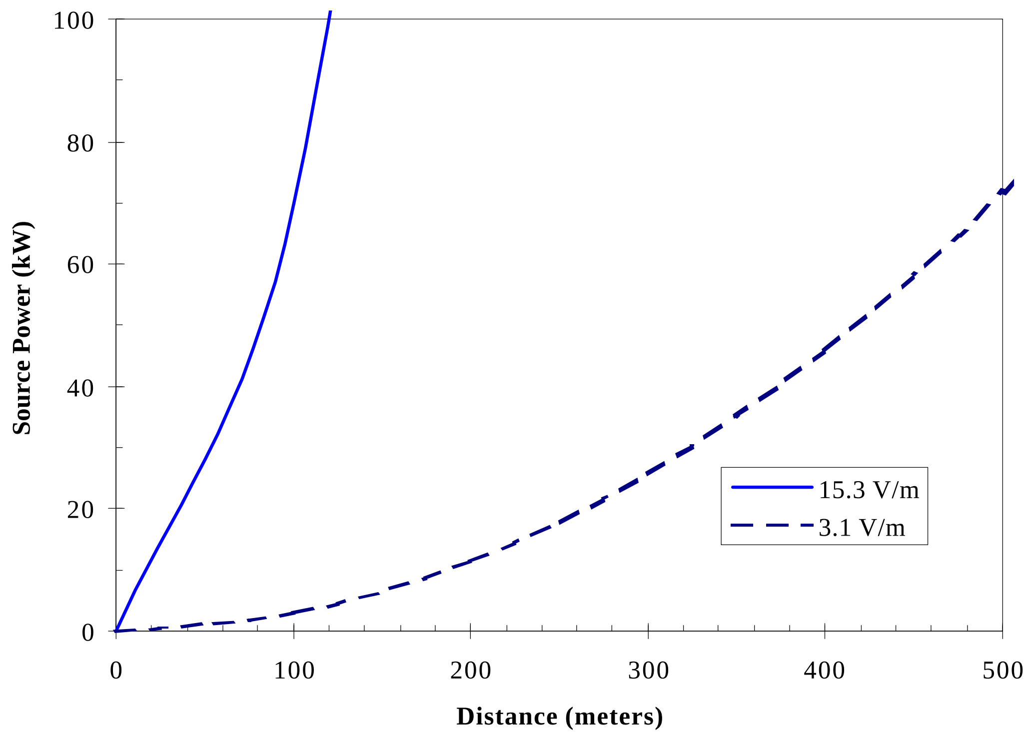

Figure 4.4. Relationship of RF Source Power and Distance From Source, FM Stations

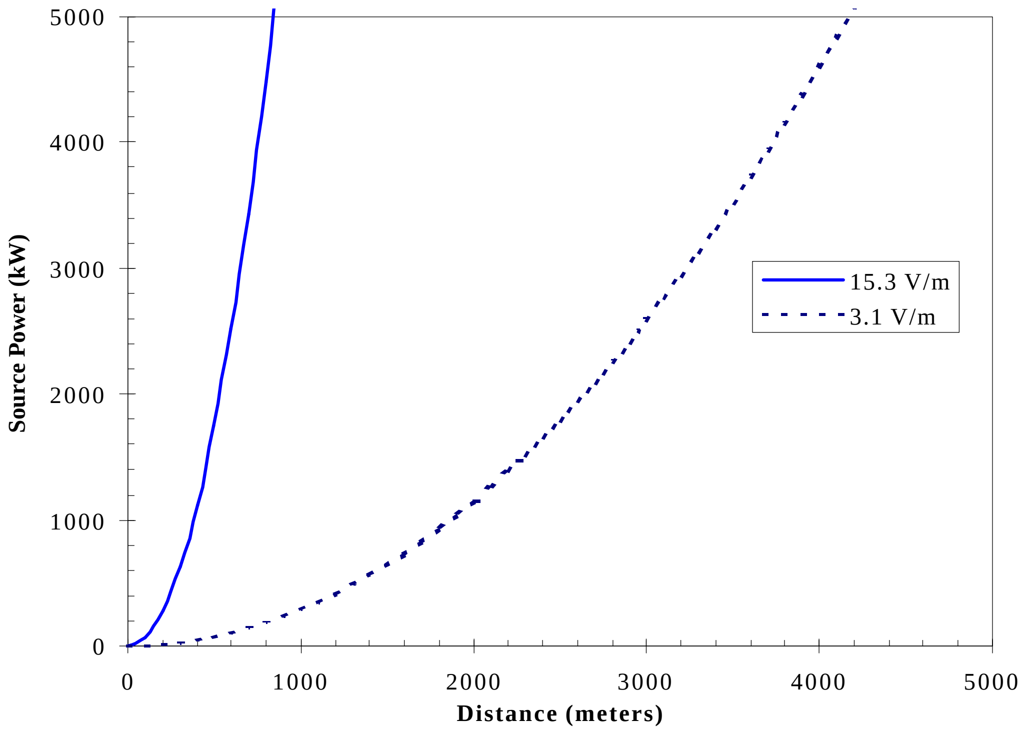

Figure 4.5. Relationship of RF Source Power and Distance From Source, TV and Radar Stations

If in the above example the criteria were set to 1 V/m, the equipment would have to be located no less than 1.2 km from the antenna. The limitation of not installing electronic telecommunication link equipment closer than 1.2 km from a 50 kW AM broadcast station reduces the number of possible sites for telecommunication links and/or requires consideration of adding shielding to the site.

The degree of attenuation provided by an enclosure or building that may enclose the telecommunication link equipment at a particular frequency varies widely from one site to another. The shielding of a building also varies with the frequency of the RF signal, making it difficult to predict the building shielding precisely. Measurements [1] have indicated central office buildings that provide no attenuation, and even provide field enhancement. For these reasons the building shielding (attenuation) provided by a building is not considered in the discussion of Figures 4.3, 4.4, and 4.5.

Field strengths of 15.3 V/m may be present at some locations - for example 140 meters from a 50 kW nondirectional AM broadcast transmitter antenna or 94 meters in front of an 8 dB gain amateur antenna fed with 1.5 kW peak envelope power. Therefore, it is possible to observe 15.3 V/m electric fields at telecommunications links sites.

GR-1089 [2] specifies a radiated immunity level of 15.3 V/m peak (8.5 V/m unmodulated). Equipment designs that meet this limit for radiated immunity (electric fields) in specific frequency bands have not experienced interference from radiated fields.

Considering that 15.3 V/m may be present at a telecommunication link site and that the present conditional requirement of 15.3 V/m peak has safeguarded equipment from EMI, equipment to be operated in a severe electromagnetic environment should meet a radiated immunity limit of 15.3 V/m peak.

The 15.3 V/m peak limit for immunity is specified to prevent interference to equipment located within approximately 3 km from high-powered transmitters. The limit also provides an additional margin against interference from noncompliant equipment that may be nearby, and from spurious emissions from portable tools, appliances, welding equipment, etc.

4.2.2.2 Broadband EMI sources

Broadband interference is that which is produced at a fairly constant energy level over a wide range of frequencies. Some sources of this interference are electric motors, combustion engines, and electrostatic discharges.

<u>Non-Intentional Sources</u>

Discharge currents developed during ESD tests can have peak currents of tens of amperes, and can contain significant spectral components in the frequency range of 10 to 1000 MHZ. The currents produce broadband electromagnetic fields. Thus, conformity of telecommunication link equipment to standards for ESDs will also indicate that the equipment has an inherent degree of hardness to broadband electromagnetic fields.

ANSI Tl.308-1996 [3] specifies that test procedures should be in accordance with the second edition (1991-04) of International Standard IEC 801-2 [4], clauses 7 and 8. The first edition of International Standard IEC 801-2 specified characteristics such as rise times and peak values for calibration of discharge currents. However, in practice it had been difficult to ensure that these characteristics were always realized during testing. For example, the air-discharge technique involves charging the ESD generator to the specified voltage and then moving the discharge electrode to the EUT until a discharge occurs. There is no practical way of controlling the motion of the electrode, and different approach modes have resulted in different rise times for the discharge current at a given voltage level. Further, the first edition of International Standard IEC 801-2 specified the discharges be applied to the earth reference plane. Application of the discharges to the earth reference plane does not simulate discharges to other nearby equipment that may generate vertical, and/or horizontal electromagnetic fields.

In recognition of these and other deficiencies of air-discharge tests, the second edition of International Standard IEC 801-2 specifies contact discharge as the preferred method. This method ensures repeatability and that the severity of the tests increases with the test voltage level. In addition, IEC 801-2 second edition specifies contact discharges to vertical and horizontal coupling planes to simulate discharges to nearby objects. Also, the waveform that the second edition specifies for discharge current includes an initial current peak whose rise time (0.7 to 1 ns) is about one-fifth that of the single peak calibration waveform of the first edition. This increases both the high-frequency content of the current and the magnitudes of the fields produced by it. For these reasons, the direct contact method of Reference 4 has been adopted for this protective measure.

4.2.2.3 Explanation of formulas for calculating electric field strength

Different formulas are used to calculate the worst-case electric field levels from AM, FM, and TV broadcast stations, and radar. The following formulas [5] give a reasonably accurate estimate of the electric field strength under ideal conditions for distances beyond 91 meters (near-field) from the antenna.

AM:

$$\mathrm{Field\,Strength(V/m)} = 304.8\frac{\sqrt{\mathrm{ERP(kW)}}}{\mathrm{d(m)}}$$

FM, TV, and Radar:

$$\mathrm{Field\,Strength(V/m)} = 182.9\frac{\sqrt{\mathrm{ERP(kW)}}}{\mathrm{d(m)}}$$

where

ERP is the effective radiated power in kilowatts, and
d is the distance to the antenna in meters.

4.3 References

1. D. N. Heirman, "Broadcast Electromagnetic Interference Environment Near Telephone Equipment," IEEE 1976 National Telecommunications Conference, pp. 28.5-1 -28.5-5, November 29 -December 1, 1976.

2. GR-1089-CORE, *Electromagnetic Compatibility and Electrical Safety - Generic Criteria for Network Telecommunications Equipment*, Issue 1, November 1994, Revision 1, December 1996

3. American National Standard for Telecommunications, *Central Office Equipment - Electrostatic Discharge Requirements - Immunity Requirements*, ANSI T1.308-1996.

4. International Electrotechnical Commission Standard, *Electromagnetic Compatibility for Industrial-Process Measurement and Control Equipment*, Part 2: Electrostatic Discharge Requirements, International Standard IEC 801-2, second edition, 1991.

5. Adapted from CCIR, Vol. II, Propagation, Recommendation 368.

6. Federal Communications commission, Part 73 of Chapter 1 of Title 47 of the Code of Federal Regulations.

7. ANSI C63.12-1987, *American National Standard for Recommended Practice for Electromagnetic Compatibility Limits*.

8. Bell System Practice 760-220-100, *RFI Shielding*, Issue 2, January 1978.

9. *Transmission Line Reference Book*, J. J. LaForest, ed., Electric Power Research Institute.

10. "Protection of Telecommunication Links from Physical Stress," Technical Information Bulletin 93-9, NCS TIB 93-9.

11. "Multitier Specification for NSEP Enhancement of Fiber Optic Long-Distance Telecommunication Networks," Volume II, D. Peach, NTIA Report 87-226.

12. "NSEP Fiber Optics System Study, Background Report: Nuclear Effects on Fiber Optic Transmission Systems," J. Hull, NTIA Report 87-227.

5.0 OPERATIONAL TEMPERATURE THREATS

5.1 Above Baseline Characterization

5.1.1 Exposure to high temperatures

The mechanical degradation behavior of lightguide fibers can be predicted at temperatures below 100°C. It is assumed that the relations applied below this temperature will continue to be valid above 100°C and thus the prediction is that the water will continue to become more aggressive (exponentially) with an increase in temperature at a constant water activity. The critical issue then becomes one of the stability of the polymer coating. Most commonly used coatings will degrade rapidly above 100°C, thus leaving the fiber unprotected. In cases where such temperatures are possible, alternate coatings should be employed.

5.1.2 Exposure to fire

The above baseline threat from fires external to the links structure is fires from both man-made and natural sources with heat release rates above 10 megawatts. Examples of such fires are:

- forest fires
- flammable liquid fires from fuel spills, vehicular crashes, etc.
- flammable gas fires from pipeline breaks, trucks, railroad tanker cars, etc.
- adjacent building fires

The above baseline threat from fires internal to the links structure is fires with a heat release rate of approximately 50 to 100 kilowatts in the area of origin. An example of this threat is a self-sustaining fire in the cables in a cable entrance facility.

5.2 Rationale

5.2.1 Exposure to steam

Optical fibers are normally considered operational over the temperature range of -40 to + 85°C.[1] Clearly there will be occasions when either short term, or even continuous exposure to higher temperatures may be necessary. Except for polyimide and possibly some metallic coatings, none of the currently used polymer coatings will withstand temperatures above 85°C for even short times. Thus, either a polyimide or a suitable metallic coating must be specified, or the temperature which the fiber experiences must in some way be restricted to less than 85°C.

5.2.2 Exposure to fire

5.2.2.1 Location

All locations are vulnerable to damage from fire. Wherever there is sufficient oxygen to support combustion and the possibility of sufficient fuel and an ignition source being present, there is a risk of an above baseline fire event.

This description includes most locations where telephone links exist, aerial cable, cable in tunnels, manholes, and other underground locations exposed to air, pole and pad mounted equipment, cable vaults, microwave antennas, etc. The cable is particularly vulnerable due to the relative ease of ignition and flame spread of its polyethylene (PE) insulation. The most notable exception is probably the buried cable plant that is truly buried in the earth or concrete.

In the urban environment, the risk of an above baseline fire comes from many sources. The cable plant under the street is vulnerable to fires resulting from fuel spills, and gas pipeline ruptures or explosions. The aerial plant and any above ground enclosure are vulnerable to fires from vehicular crashes, and major building fires. The cable entering a building in a cable entrance facility (CEF) is vulnerable to any fire that might originate there, again due to its fire ignition and spread characteristics.

In the suburban or rural environment, all of the above-ground plant is vulnerable to forest fires, as well as the vehicular crashes, fuel spills, pipeline ruptures, and major building fires.

5.2.2.2 Occurrence

The examples of above baseline events capable of producing a 10 megawatt fire are not all that rare. Taken together there are probably hundreds of these events around the country each year. The issue is how often these events impact the telecommunications links.

Although relatively rare, fire events have caused damage to link elements. As reported in NCS TIB 93-9, a study of fiber optic cable failures indicated that fires caused 4.0% of the total reported failures.[2] The FCC Reportable Outages Library had only four listings of fire-related cable failures, from 1992 to mid-1997, that resulted in outages meeting the FCC criteria.[3] In two of the four events the fire involved power utility hardware, the third was a grass fire, and the fourth was an unspecified fire source in a city. The latter two of these events could be construed to be above baseline events.

5.2.2.3 Severity

The above baseline fire event is, by its nature, a severe fire event. The word severe is somewhat subjective, particularly when it comes to fire. A severe impact can occur from a relatively small fire in the wrong location. One numerical measure of fire severity that has gained wide acceptance in the fire science community is the concept of heat release rate, which is the amount of heat being generated at any point in time by the combustion process. It is probably the best single indicator of the likelihood of damage to surrounding objects.

For purposes of this report an above baseline fire, outside of a building, is one that grows to a size where the instantaneous heat release rate approaches 10 megawatts. This is a size of fire that has the potential to reach and destroy aerial cables, and is likely to cause severe damage to anything inside a typical links enclosure. Any of the fire scenarios presented as threats to the links outside of a CEF could easily reach the 10 megawatt heat release rate. An above baseline fire, inside a CEF or other links enclosure, is one that grows to a size where the instantaneous heat release rate reaches 50-100 kilowatts. This size of fire can easily damage the fiber optic and copper cables in these facilities, and would likely continue to spread in the polyethylene (PE) insulated cables that enter the facility or enclosure from the outside.

5.2.3 Fire severity analysis

The following examples illustrate that a 10 megawatt fire is not difficult to obtain:

— Forest fire - wood, in a vertical orientation, burns at about 100 - 200 kilowatts per square meter of surface area. Excluding underbrush, branches and leaves, it would take about 10 - 20 trees 0.3 m in diameter, 5 m high burning at once to yield 10 megawatts.

— Fuel fire - a gasoline pool fire burns at the rate of about 0.05 kg per second per square meter of pool area, for pools greater than 2 meters in diameter. This equates to 2.2 megawatts per square meter. Thus, with a pool diameter as small as 1.4 m, a 10 megawatt fire results.

— Pipeline fire - the average house in a northern climate has a furnace that produces about 20 kilowatts of heat energy, thus a pipeline fire burning the equivalent gas utilized by the furnaces of only 500 houses would produce a 10 megawatt fire.

5.3 References

1. Biswas, Kurkjian and Gebizlioglu, “Reliability of Optical Fibers in Steam and Petrochemical Environments”, IWCS, 1996, pg 456-463.

2. Technical Information Bulletin 93-9, *Protection of Telecommunication Links from Physical Stress*, National Communications System.

3. Bellcore, “FCC Reportable Outages Library,” available on the World Wide Web at http://www.bellcore.com.

6.0 THREATS FROM WIND AND ICE

6.1 Above Baseline Characterization

This section discusses the proposed above baseline threat to telecommunications links from the effects of wind and ice. The baseline standard for physical stresses caused by wind and ice is presented in ANSI T1.328-1995.[1] TIB 93.9 contains the technical rationale for the baseline standard.[2] When comparing the baseline threat to the above-baseline threat, one will find that the intensity has increased. The rationale for these changes in intensity is included in the document.

It is important to have an understanding of the relationship between the intersection of nature and population. This is fundamental for the development and evaluation of above baseline threats. As the population continues to grow or migrate, so does the area of intersection with natural hazards.

The threat to public communications networks due to wind and ice which has been established and measured in previous documentation can be attributed solely to its effects on aerial plant. There are several standards which have already been established that govern the construction and loading of aerial plant. Two examples are the National Electrical Safety Code (NESC) and the Guidelines for Electrical Transmission Line Structural Loading.[3][4]

The NESC sets forth two primary construction grades, grades B and C, which are to be applied to the telecommunications industry. Grade C represents the minimum grade which should be used for construction of joint-use facilities, while Grade B is the more stringent. An above baseline would suggest the use of Grade B construction in light and medium loading areas and even overload factors used for construction for heavy loading areas.

The above baseline construction techniques would be used to protect against 3, 4 and 5 category hurricanes, tornadoes, or the unlikely, yet possible, event of exposure to heavy ice buildup and maximum wind speeds occurring simultaneously.

6.2 Rationale

The world's fastest wind gust ever recorded on land took place on April 12, 1934, atop Mount Washington, NH during a huge spring storm. This storm yielded a gust of 231 mph. The fastest wind gust recorded at a low elevation was 207 mph. This occurred on March 8, 1972, at a U.S. Air Force Base in Thule, Greenland.

6.2.1 Hurricanes

Hurricanes are high energy high impact events that are costly and deadly when they hit densely populated areas. By the year 2000, population growth in coastal areas subject to hurricanes will subject 25% of the U.S. population (67 million people) to the potential danger and destruction of hurricanes. Property losses due to hurricanes have grown rapidly in this century and are expected to grow more rapidly in the future.

Hurricanes are rated by their potential for damage on a scale of one to five. The table below is a breakdown of the average wind values and the likely level of damage for each of the five hurricane categories. Wind speed is given in miles per hour.

Category	Damage	Winds
1	minimal	74-95
2	moderate	96-110
3	extensive	111-130
4	extreme	131-155
5	catastrophic	>155

Table 6.1. Hurricane Wind Speeds

Listed below are several examples of the above baseline hurricanes (i.e., Category 3 or higher) that have recently taken place in the United States.

1. September 5, 1996 Hurricane Fran, a Category 3 hurricane with winds of 115 miles per hour, made landfall on the North Carolina coast at Cape Fear, an area that had already been hit by Hurricane Bertha in July of the same year.

2. October, 1995 Hurricane Opal, a Category 3 hurricane strikes Florida, Alabama, western Georgia, eastern Tennessee, and the western Carolinas.

3. September 1992 Hurricane Iniki, a Category 4 hurricane hits Hawaiian island of Kauai.

4. August 1992 Hurricane Andrew, a Category 4 hurricane hits Florida and Louisiana.

5. September 1989 Hurricane Hugo, a Category 4 hurricane devastates South and North Carolina after hitting Puerto Rico and U.S. Virgin Islands.

6.2.2 Tornadoes

A tornado is defined as a violently rotating column of air extending from a thunderstorm to the ground. The most violent tornadoes are capable of tremendous destruction with wind speeds of 250 mph of more. Damage paths can be in excess of one mile wide and 50 miles long. In an average year, 800 tornadoes are reported nationwide. The highest winds measured in a tornado, before the anemometer was destroyed, was a 151-mph wind gust at 33 feet above the ground. The measurement was recorded in Tecumseh, Michigan in 1965.

Fujita Scale damage descriptions

The Fujita Scale uses numbers from zero through five and the ratings are based on the amount and type of wind damage. The scale had been calculated through F-12, which is Mach 1 - the speed of sound (750 mph) - but tornado wind speeds are not expected to reach these speeds; see the F-6 description below.

F-0 Gale tornado (40-72 mph): Some damage to chimneys; breaks branches off trees; pushes over shallow-rooted trees; damages sign boards.

F-1 Moderate tornado (73-112 mph): The lower limit is the beginning of hurricane wind speed; peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off the roads; attached garages may be destroyed.

F-2 Significant tornado (113-157 mph): Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light object missiles generated.

F-3 Severe tornado (158-206 mph): Roof and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted.

F-4 Devastating tornado (207-260 mph): Well-constructed houses leveled; structures with weak foundations blown off some distance; cars thrown and large missiles generated.

F-5 Incredible tornado (261-318 mph): Strong frame houses lifted off foundations and carried considerable distances to disintegrate; automobile sized missiles fly through the air in excess of 100 meters; trees debarked; steel-reinforced concrete structures badly damaged.

F-6 Inconceivable tornado (319-379 mph): These winds are very unlikely. The small area of damage they might produce would probably not be recognizable along with the mess produced by F-4 and F-5 wind that would surround the F-6 winds. Missiles, such as cars and refrigerators would do serious secondary damage that could not be directly identified as F-6 damage. If this level is ever achieved, evidence for it might only be found in some manner of ground swirl pattern, for it may never be identifiable through engineering studies.

The maps below show reported Tornadoes by State for several past years.

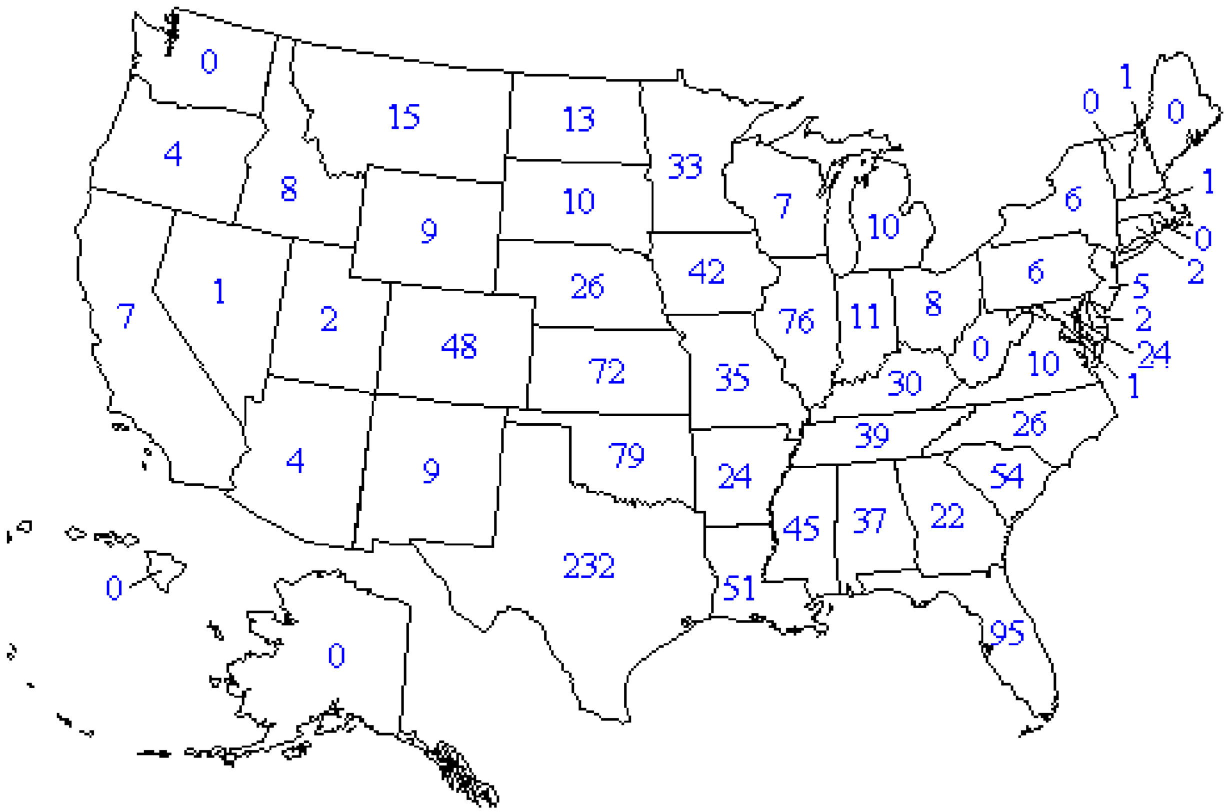

Figure 6.1. 1995 Tornadoes

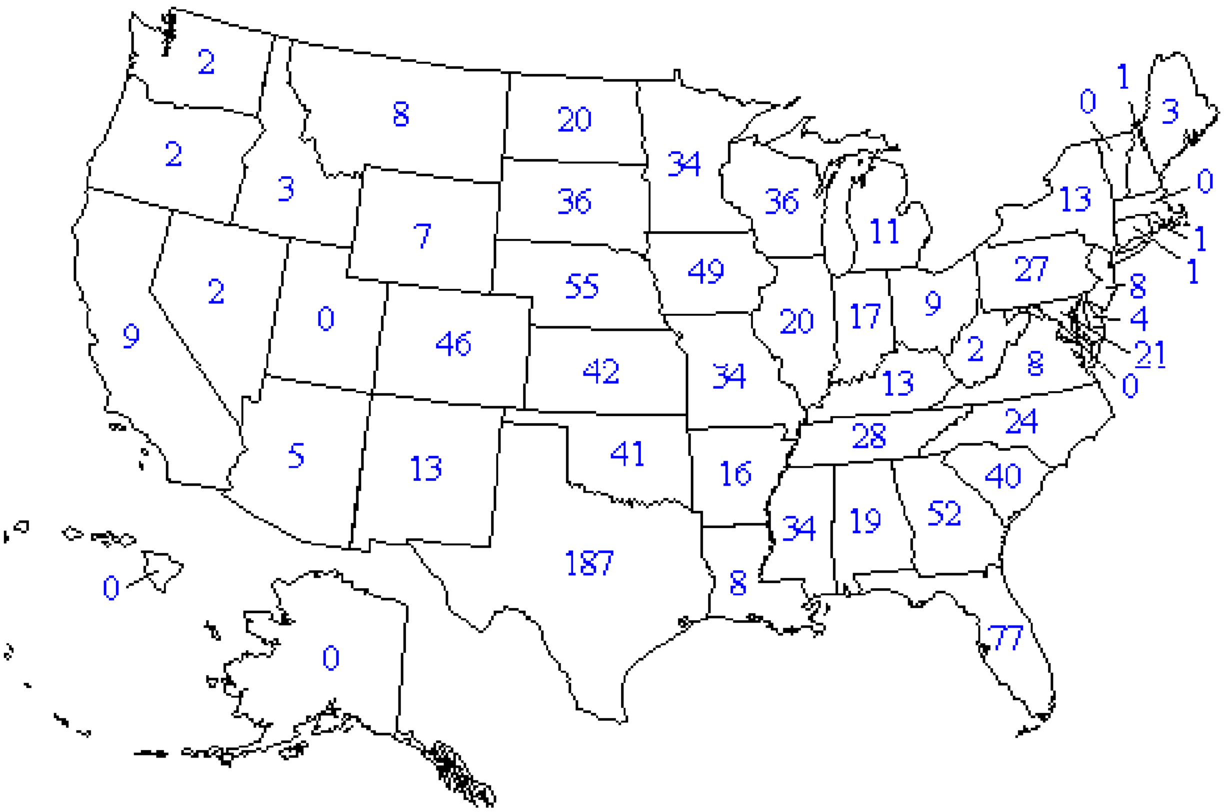

Figure 6.2. 1994 Tornadoes

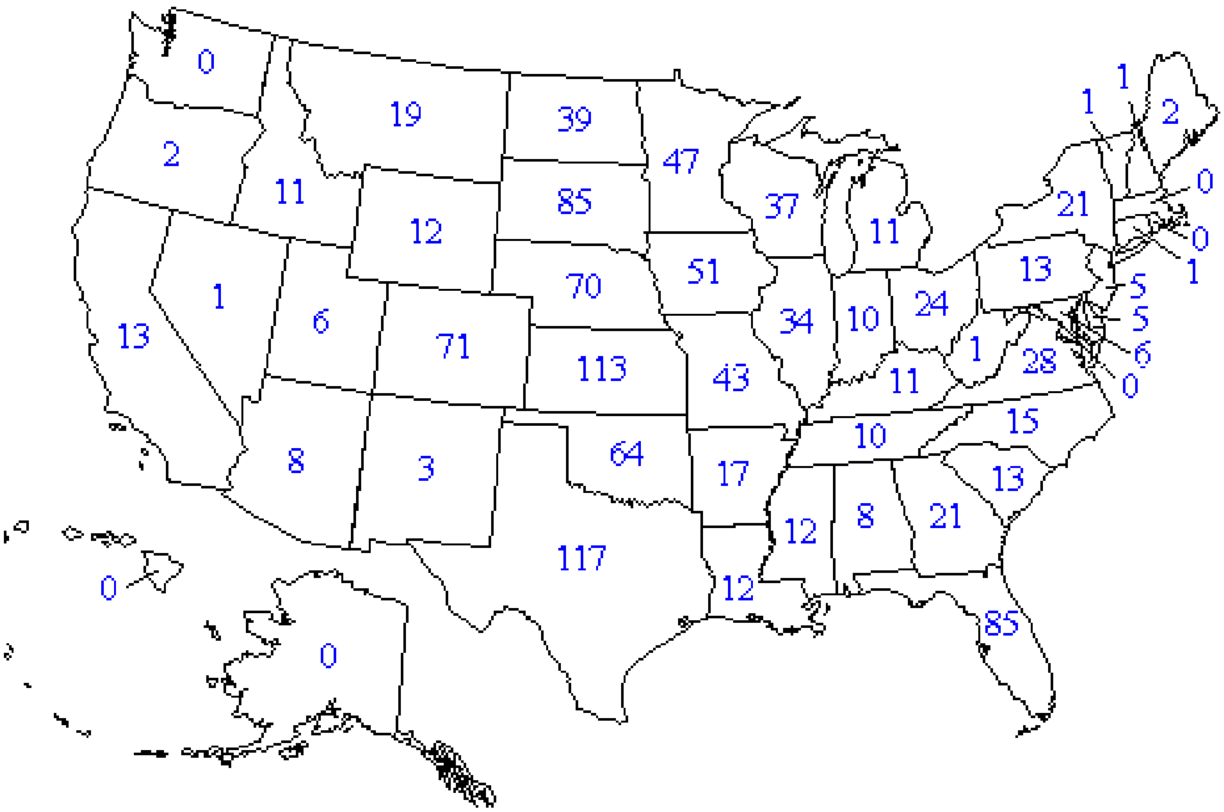

Figure 6.3. 1993 Tornadoes

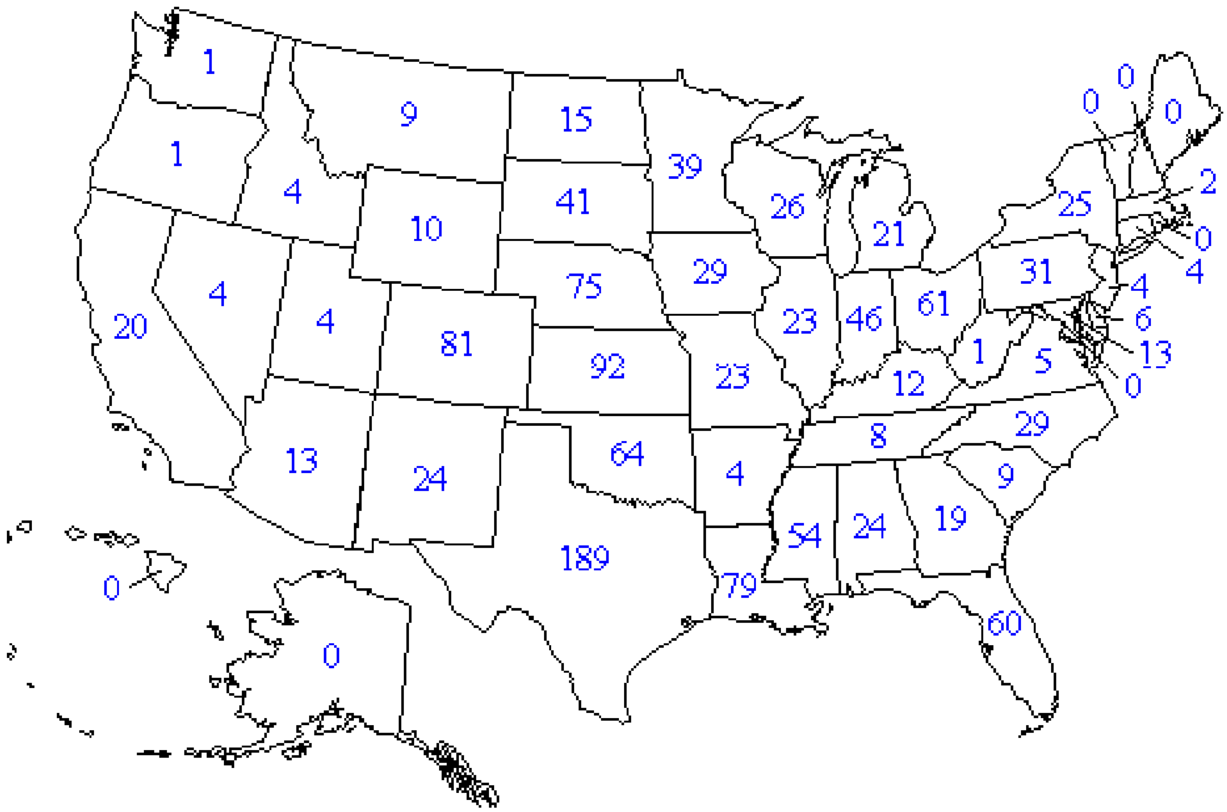

Figure 6.4. 1992 Tornadoes

6.2.3 Storm of the century

March 12-15, 1993, a storm now called "The Storm of the Century" struck the eastern seaboard. Thousands of people were isolated by record snowfalls, especially in the mountains of Georgia, North Carolina, and Virginia. For the first time, every major airport on the east coast was closed at one time or another by the storm. Snowfall rates of 2-3 inches per hour were common. In areas to the east <u>wind-driven sleet</u> occurred, with central New Jersey reporting 2.5 inches of sleet on top of 12 inches of snow. Wind gusts up to 144 mph were recorded on Mount Washington, NH, 109 mph in Dry Tortugas, FL, 101 mph on Flattop Mountain, NC, 89 mph in Fire Island, NY, and 81 mph in Boston, Ma.

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7.0 CONSTRUCTION THREATS

7.1 Above Baseline Characterization

The National Electrical Safety Code sets forth standardized practices for nearly all type of construction to protect against a reasonable level of man-made threats. However, as the number of links continues to grow due to the expanse of the infrastructure, the level of threat in high-construction or highly populated areas may grow beyond that which was considered reasonable in the NESC. Under these circumstances, the use of an above baseline standard may be warranted.

Furthermore, an above baseline could go beyond high construction area protection. As can be demonstrated through on-site inspections, there exists in certain areas, a threat of sabotage or vandalism and theft. The proposed level for the above baseline threat could include these issues as well as vehicular damage and human error.

The greatest threat to telecommunications links from construction activities is that of damage to links elements caused by digging activity. This threat is apparent both in locations with significant construction activity and at locations with less activity, where digging takes place without prior notification of telecommunications links owners.

7.2 Rationale

A response to a question to the Network Reliability Council indicates that, in 1993, "the greatest single threat to telecommunications network reliability in the U.S. is damage to underground transmission facilities caused primarily by digging activity." The response also includes a statement that since then the situation has not improved. In the period from 1993-1996, more than 50 percent of major, reportable facility outages were caused by dig-ups.

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8.0 THREATS TO TELECOMMUNICATIONS LINKS FROM CORROSION

8.1 Above Baseline Characterization

8.1.1 Below-ground telecommunications links

The threats to below-ground telecommunication links from corrosion include the presence of dc stray current, chemically corrosive environments, and bacterial growth. Environments with dc stray current include inner-city subsurface electric rail systems and standby ground return electrode systems for high-voltage direct current power transmission facilities. Underground cables in proximity to these environments are at risk from these threats.

Extremely corrosive environments are associated with areas of chemical manufacturing and heavy industry, seacoast locations, and areas near heavy truck and automobile traffic corridors.

Bacterial corrosion occurs in areas with naturally high levels of bacterial growth that are part of the locally normal biomass decomposition environment.

8.1.2 Above-ground telecommunications links

The above baseline threat of corrosion to above-ground telecommunications links comes from atmospheric contamination, stress corrosion cracking of metals and plastics, ionic pollutants, temperature cycling, and exposure to corrosive and hygroscopic dust.

Atmospheric contamination is associated with chemical manufacturing and heavy industry locations, seacoast locations, and locations near heavy truck and automobile traffic.

Stress corrosion occurs in either metallic alloys or polymeric materials that are placed under high stresses. In addition, the plastics are more susceptible to stress-induced cracking under certain severe environments.

8.2 Rationale

8.2.1 Below-ground telecommunications links

8.2.1.1 DC stray current corrosion

Some plant equipment such as buried cable, is located in areas that are prone to high levels of stray dc current. Unlike most corrosion processes that occur within the below-ground telecommunications plant, which are uniform, dc current driven potential can be very localized. This localization can create high corrosion current densities and rapid failure of link systems.

Some metals such as aluminum shielded coaxial cable that is used for broadband telecommunications links are more susceptible to stray current corrosion than the more noble copper/copper alloys, stainless steels, lead, and iron. Since these links typically carry voluminous amounts of digital data in the form of packets, their loss can therefore be compared to loss of a fiber optic transmission facility. Powering of these links is still a debated issue—the tradeoff being susceptibility to corrosion, efficiency, power transmission and cost. Operators of these broadband links often prefer ground isolation for their metallic plant as a strategy to prevent stray current corrosion and damage from power cross events.

8.2.1.2 Chemical corrosion

Chemical corrosion is all other sources of corrosion that are not due to stray currents. Typically this chemical corrosion occurs when metallic components of the telecommunications facility react with the environment. Locations with extreme environments can cause rapid (several months to a year) failure of telecommunications links.

Some metals such as aluminum that are significantly less noble than stainless steels and copper or copper alloys can be rapidly attacked by various chemical corrosion processes. Mitigation of extreme chemical corrosion failures requires the use of chloride resistant stainless steels, copper alloys and careful attention to galvanic effects. This type of corrosion can also be mitigated by use of polymeric coatings and chemical resistant paint.

8.2.1.3 Bacterial corrosion

Certain locations have naturally high levels of bacterial growth that are part of the locally normal biomass decomposition environment. These areas are more prone to bacterial stimulated corrosion than normal manhole stagnant water. This type of corrosion leads to very rapid failure of galvanized steel hardware, deterioration of metallic cable shield, and hydrogen-stress cracking of stressed (support) hardware. Some types of anaerobic soils, such as clays promote rapid corrosion of buried plant equipment.

8.2.2 Above-ground corrosion

This above baseline consideration will extend the discussion of threats to include corrosion of nonmetallic materials such as plastics, ceramics, wood poles and the other transmission and support hardware products used in the aerial telecommunications links. Furthermore, the future proliferation of digital services operating at higher (130+) voltages over a variety of frequencies, with stringent reliability demands will place higher demands on the corrosion resistance of the telecommunication links.

8.2.2.1 Corrosion of metals from atmospheric contamination

Whereas the effect of weather may be considered a normal stress on aerial plant, areas (usually urban) of high concentrations of atmospheric pollutants can cause significant additional stress to above ground plant facilities. In particular acidic gases and ionic aerosols can cause rapid degradation of plant hardware and active electronic facilities such as controlled environment equipment cabinets which require ventilation. These airborne pollutants can cause significant loss of electronic equipment reliability in a short time span (12 months). The soiling and corrosion which occur on this equipment can cause intermittent and hard to locate failures.

Examples of extreme atmospheric corrosion conditions include:
— Chemical manufacturing and heavy industry locations.
— Seacoast locations.
— Locations near heavy truck and automobile traffic corridors.

8.2.2.2 Stress corrosion of specific alloys

Some alloys and copper alloys in particular are susceptible to stress corrosion cracking. Generally plant facilities that are placed under high stresses are fabricated of steel, cast iron, or stainless steels. Because of the catastrophic nature of failures of aerial support hardware, copper alloys should be avoided when possible for these applications. When copper alloys are employed in support or suspension applications, the component must be evaluated for resistance to stress corrosion.

8.2.2.3 Stress-induced cracking/crazing of plastics

Polymeric materials that are used for plant equipment enclosures must withstand aggressive environments. These environments may cause not only deterioration of seals, but also deterioration of the main bodies of enclosures. The threats include:
— Areas of intense solar radiation - UV solar radiation.
— Areas with extended periods of high temperatures - mold stress relief that causes physical distortion of the enclosure, leading to loss of protection for the enclosed equipment and cracking of insulation on plastic insulated conductors.
— Severe cold climates that cause embattlement and structural failure of the enclosure.
— Flexure fatigue leading to microcracking, which creates cavities which support bacterial growths and accelerated oxidation of surfaces.

8.2.2.4 Effects of ionic pollutants

High levels (above the 96 percentile norms) of atmospheric ionic aerosols can cause the formation of leakage paths between conductors on many types of circuit paths. The local loop circuit is tolerant of this phenomenon, usually causing a degraded circuit but not loss of circuit path. Circuits which carry data in the high frequency (>100 kHz) to radio frequencies (>1 MHZ) can fail due to this type of stress.

8.2.2.5 Effects of temperature cycling with humidity

Environments which have large diurnal swings of temperature and humidity place additional stress on above-ground facilities. Frequently a ‘sealed’ closure does not leak water but allows a small exchange of atmosphere (called breathing) during the diurnal thermal cycle. This exchange brings in atmospheric water which can condense within the watertight closure leading to accelerated corrosion.

8.2.2.6 Effects of corrosive and hygroscopic dust exposure

Areas of with high levels of atmospheric particulate contamination can cause soiling of contacts and electronic circuits. This particulate contamination is hygroscopic, retaining water and not drying out during periods of low humidity. This sets conditions for electrolytic leakage or corrosion within affected facilities. This type of stress often manifests itself as untraceable intermittent faults.

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9.0 THREATS FROM LIGHTNING AND EXPOSURE TO AC POWER

9.1 Above Baseline Characterization

Power faults and lightning strokes to telecommunication links can have local and system-wide effects. Local effects include mechanical and thermal damage to the cable at the point of strike or a fault. System-wide effects include coupled or conducted voltages and currents that can propagate along the cables and impinge on components of the link.

9.1.1 Lightning

The above baseline lightning threat is defined as direct lightning stroke to a cable with metallic components having a peak current of 200 kA and time to half value of 350 microseconds. The ability of the cable to withstand such strokes can be determined using the laboratory procedure included in Standard TIA/EIA-455.

9.1.2 Power fault

The above baseline power fault threat is defined as a direct low-impedance contact between an aerial telecommunications cable and a power conductor from a power system installed immediately above the telecommunications conductors on joint-use poles. The current withstand requirements for such contact depend on the rating of the overcurrent protection devices for the power conductor. In the majority of locations, the worst-case scenario is a contact with a power conductor protected by a 200T fuse resulting in fault current of 1500 A or greater.

Direct contact for buried cable is rare and difficult to mitigate, so that an above baseline level is not defined.

9.2 Rationale

9.2.1 Lightning

A lightning stroke develops in several steps. The first step is the development of a stepped leader that lowers the electric charge from the cloud toward earth and then establishes an electrical path between the cloud and an object on the ground. Once a path is formed, the next event is a return stroke that consists of a rapid discharge and results in a short but powerful current pulse. The first return stroke may be followed by one or more dart leaders that reenergize and result in additional return strokes. The most destructive effects of lightning are associated with the current pulse that occurs during the first return stroke. Subsequent return strokes typically produce less current.

Lightning currents produce mechanical, thermal and electromagnetic effects. The thermal effects of lightning include overheating, melting or vaporization of or nearby the conducting path of the lightning current. The mechanical effects include deformation, ripping or shattering of the objects whose components carry the current. The electromagnetic effects include induction of surge currents and voltages in nearby objects or in other components of the object struck by lightning. The induced surges may, in turn, have their own destructive or disruptive thermal, mechanical or electromagnetic effects. The mechanical and thermal effects are generally confined to the object that is struck by lightning directly, while the electromagnetic effects can propagate a significant distance away from the stroke point.

In determining the lightning threat, the first step is to evaluate the probability of a direct stroke to the link. The magnitude of the current pulse resulting from a direct stroke is an order of magnitude greater that the magnitude of an induced current surge. Thus if a threat of a direct lightning strike exists, such threat surpasses any threat of induced surges. The expected number of direct strikes to a cable, without lightning shielding, in a given year, N, can be estimated by

$N = N_g 2DL$ for buried cables, or

$N = N_g 6HL$ for aerial cables, where

N_g is the lightning flash density (number of strokes per square meter per year); if a map of N_g is not available, it may be estimated by the use of the following relationship:

$N_g = 0.004 \times T_d^{\,1.25} \times 10^6$ where T_d is the number of thunderstorm days per year.

L is the length of the cable in meters

H is the height of the cable

D is the equivalent arcing distance:

$$D = 0.482\sqrt{\rho} \qquad \text{for} \qquad \rho < 100 \ m-\Omega$$

$$D = 0.283\sqrt{\rho} \qquad \text{for} \qquad \rho > 1000 \ m-\Omega$$

$$D = 0.191(\sqrt{\rho} - 10) + 4.82 \qquad \text{for} \quad 100 < \rho < 1000 \ m-\Omega$$

Using this estimate, the threat of a direct lightning strike represents a threat for the majority of cable installations. This is confirmed by considerable experience of direct lightning strikes to cables. The preceding discussion applies to cables without lightning shielding; such shielding may be provided intentionally as a lightning protection measure or arise incidentally as a result of joint-use with power conductors. However, there are sufficient number of unshielded communications links, that considering a link to be exposed to a direct lightning stroke as an above baseline threat is warranted.

Once, the threat of a direct stroke to a link is recognized, the parameters of the current pulse must be defined. Since the threat is a direct stroke, the damage mechanism is thermal and mechanical and the parameters of concern are lightning current duration and magnitude. The rate of rise of the lightning current, which is important for determining the electromagnetic effects of lightning, is less important and will not be specified.

The parameters of lightning strokes vary statistically. They have been studied extensively; an internationally accepted classification appears in standards IEC 1024-1-1 and IEC 1312-1. These standards define three levels; since an above baseline threat is under consideration, the most severe (Level I) one is chosen. It is a current pulse with a peak of 200 kA and time to half-value of 350 microseconds.

9.2.2 Power fault

Many of the considerations that apply to the lightning threat apply to the power-fault threat as well. Power contact between an energized phase conductor and power system neutral or a communications cable lead to a flow of large currents on the telecommunications conductors. This current can have mechanical, thermal and electromagnetic effects. The destructive effects of a direct contact between power cable and communications cable are much more severe than those resulting from currents that arise when the power fault does not involve direct contact.

Although extensive statistics on the number of power contact are not well established, there is ample experience to indicate that power contact in aerial plant occurs sufficiently often to warrant considering it an above baseline threat. When contact occurs, its effects depend on the duration and magnitude of the power-fault current. The magnitude of the fault current depends on the voltage of the faulted cable and the impedances of the components of the fault circuit. The impedance of the communications cable to ground is low due to the multiple connections between the cable and the multi-grounded power neutral required by the National Electrical Safety Code (ANSI C2). Thus, a low-impedance contact with a communications cable, which is expected to produce the most severe destructive effects, should result in a fault current exceeding 1500 A.

The duration of the fault at a given magnitude is a function of the overcurrent protection for the faulted cable. Overcurrent protection with a larger rating permits longer duration currents. The largest overcurrent protection device in common use in the commercial ac power distribution network is the 200T fuse.

For buried cable the number of incidences of direct contact between power cables and communications cables is believed to be low although not zero. It is believed that the number of power contacts in buried cable installations is insufficient to justify including them as an above baseline threat. Furthermore, the majority of power contacts in buried plant are associated with dig-ups. A dig-up is likely to result in a damage to buried cable regardless of the possibility of power contact, so that the underlying threat to a buried cable is the threat of dig-up and not the threat of a power contact.

Thus the above baseline power fault threat is defined as a direct low-impedance contact between an aerial telecommunications cable and a power conductor from a power system installed immediately above the telecommunications conductors on joint-use poles. The current withstand requirements for such contact depend on the rating of the overcurrent protection devices for the power conductor. In the majority of locations, the worst-case scenario is a contact with a power conductor protected by 200T fuse resulting in fault current of 1500 A or greater.

9.3 References

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10.0 THREATS FROM LOSS OF TELECOMMUNICATIONS POWER

10.1 Above Baseline Characterization

The threat to elements of telecommunications links that depend on telecommunications power is a commercial power outage that extends beyond three hours. These elements include repeaters, amplifiers, and other active elements of telecommunications links.

Since most of the telecommunications sites carry battery reserve power for three hours, that should be sufficient to protect against the majority of the commercial power outages, but rare occurrences of extended outages are still reported. Even though most telecommunication sites are equipped with emergency gen-set hook up connectors nearby their ac meters; assembling adequate numbers of generator sets and delivering them to all the sites before the reserve power is depleted is a major problem. This is especially true if the outage is related to a widespread natural disaster.

10.2 Rationale

The above baseline threats to telecommunications power systems principally arise from power utility outages that last more than three hours. These long-duration outages primarily occur as a result of either human errors/intervention or *force majeur*, such as hurricanes, ice storms, earthquakes, etc. It is expected that telecommunications (POTS) network providers would strive to provide their best effort so that calls can be made and completed even under these adverse conditions.

A Federal Communications Commission task force organized under the auspices of the Network Reliability Council has recommended the reliability goals for POTS.[1] The estimated down time for POTS was 53 minutes for all causes. About nine minutes of the 53 were unassigned and after considerable deliberations about five minutes of the nine unassigned minutes were designated for power. The five minutes of downtime translate into an availability of 99.999% under normal conditions. While no requirements exist for the reliability of telecommunications power systems to above baseline threats, redundancy of equipment and energy generation/storage sources, together with good engineering, maintenance, and installation practices, are the best lines of defense.

While 99.999% availability is high, it is achievable and in most CO based power plants the availability may be even higher - under normal conditions. In the outside plant, however, this powering reliability is at times compromised due to the vulnerability of the equipment to above baseline threats *vis a vis* environment, difficulties in reaching the site with alternate sources, vandalism, lack of adequate maintenance, etc. To fathom the magnitude of these above baseline threats, the quality of commercial power needs to be determined.

While the quality of commercial ac power provides an overall statistic of outages that occur due to disturbances in the power grid, none of the sites were directly affected by natural disasters. Hence a simplistic but valid approach would be to consider these sets of data (commercial power outage data and natural disaster data) independently.

10.2.1 Quality of commercial power

The quality of commercial 120 Vac was studied by Goldstein and Speranza.[2] They monitored the quality of commercial ac at 26 data centers within the Bell System from 1978 to 1979, and used a Polya type of distribution to describe their findings. The distribution is shown in Figure 10.1, and can be modeled by:

$$Y = 18.19 \log X + 13.32$$ - *where Y is the % Outage and X is the time in seconds*

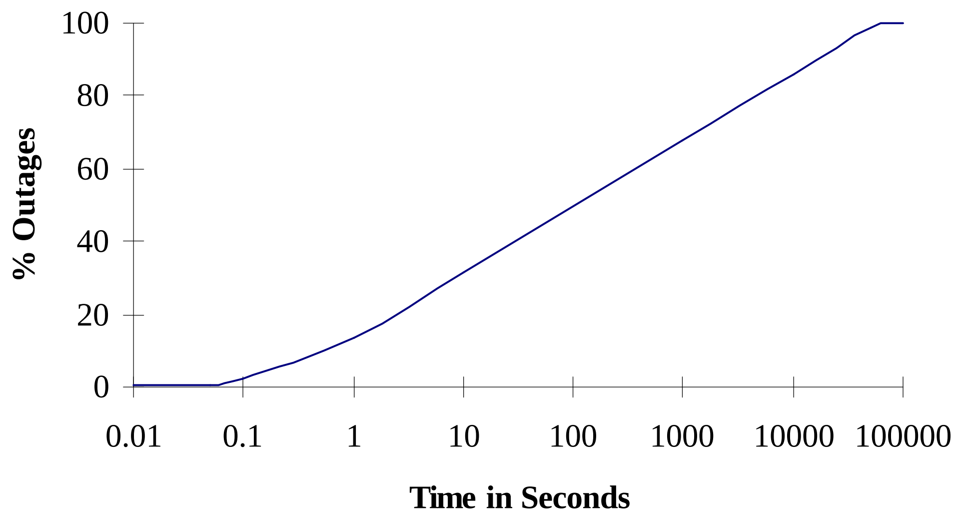

Figure 10.1. Quality of AC Power 1978-79

The correlation coefficient between this model and the data is 0.996. Therefore, the model will be used for comparison instead of discrete events. Based on this distribution, about 13.3% of the outages last more than three hours, and represent a substantial threat to telecommunications links.

Because of the high probability of long-duration (greater than three hours) commercial power outages, telecommunications network providers need to be cognizant of these threats. Planning, engineering, and disaster management measures are necessary to recover from these events and provide seamless high-quality communications.

10.2.2 Natural disasters

In addition to the general statistics on commercial power quality a list of natural disasters is provided below. This list was obtained from the Federal Emergency Management Agency (FEMA) and prepared by FEMA for the World Disaster Reduction Day seminars scheduled for 10/8/97.[3]

Table 10.1 provides a brief list of the states that experienced major natural disasters. While all COs in the affected states were probably not exposed to more than three hours of commercial power outage, it can be safely extrapolated that a significant number lost commercial power for more than three hours, periods when communications are needed the most. Hence, protection against above baseline threats to telecommunications links is imperative.

In addition to the FEMA data provided in Table 10.1, the American Red Cross provides data on the number of families that were provided with emergency assistance from 1989 to 1996 and the total expenses per year, Table 10.2. While we could not find data on the total number of COs that experienced above baseline threats, the Red Cross data help provide an estimate of the number of people that are affected severely due to above base line events.

Event	State(s)	Year	Cost
Northridge Earthquake	CA	1994	$5.6 billion
Hurricane Andrew	FL, LA	1992	$1.8 billion
Hurricane Hugo	NC, SC, VI	1989	$1.3 billion
Midwest Floods	IL, IA, KS, MN, MO, NE, ND, SD, WI	1993	$1.14 billion
Loma Prieta Earthquake	CA	1989	$836.8 million
Hurricane Marilyn	VI	1995	$545.5 million
Hurricane Fran	MD, NC, PA, SC, VA, WV	1996	$496 million
Tropical Storm Alberto	AL, FL, GA	1994	$433.4 million
Winter Storms	CA	1995	$372.2 million
Mid-Atlantic/Northeast Floods	MD, ME, NY, OH, PA, VA, VT, WV	1996	$359.4 million

Table 10.1. Top Ten Disasters Ranked by FEMA Relief Costs - 1987-1996.

Year	Number of families Assisted	Expenses
89-90	229,278	$224.4 million
90-91	104,447	$184.4 million
91-92	168,674	$187.8 million
92-93	209,180	$248.2 million
93-94	122,508	$220.9 million
94-95	124,929	$233.3 million
95-96	125,120	$216.5 million

Table 10.2. American Red Cross Disaster Relief History 1989-1996

10.3 References

1. Network Reliability Council, “A Report to the Nation,” 1993.

2. Goldstein and Speranza, “The Quality of US Commercial AC Power," Proc. of INTELECT '82.

3. Federal Emergency Management Agency, from the World Wide Web, http://www.fema.gov/nwz97/wdzday.htm.

11.0 CONCLUSIONS

11.1 Scope of This Report

This report characterizes above baseline physical threats to telecommunications links. These above baseline threats are beyond the physical stresses described in the baseline standard. Specific measures to protect against these threats are beyond the scope of this report.

The above baseline physical threats characterized in this report apply to the telecommunications links that interconnect environmentally controlled centers of PTNs. The links are fiber-optic or copper-conductor cables of trunk, feeder, and local distribution plant. The links include connection and repeater points that are on pedestals or poles, or in manholes, and that are not environmentally controlled. The termination of the links in environmentally controlled buildings, and their power sources, are included, but the buildings themselves and their contents are excluded. This report is concerned primarily with the generic features of telecommunications links rather than with specific network equipment or components.

11.2 Physical Threats

The above baseline physical stresses characterized in this report include the following:

- Vibration
- Liquid penetration in optical fiber cables
- Radiation
- Temperature
- Wind and ice
- Construction threats
- Corrosion of above-ground links
- Corrosion of below-ground links
- Lightning and exposure to ac power
- Telecommunications power

Appendix A - List of Acronyms

ANSI	American National Standards Institute
CEV	Controlled Environmental Vault
CO	Central Office
EIA	Electronic Industries Association
EMI	Electromagnetic Interference
ERP	Effective Radiated Power
ESD	Electrostatic Discharge
EUT	Equipment Under Test
FEMA	Federal Emergency Management Agency
IC	Interexchange Carrier
IEEE	Institute of Electrical and Electronics Engineers
LEC	Local Exchange Carrier
NCS	National Communications System
NEBS	Network Equipment-Building Systems
NFPA	National Fire Protection Association
NSDD	National Security Decision Directive
NSEP	National Security Emergency Preparedness
NTIA	National Telecommunications and Information Administration
PCS	Personal Communications Services
POTS	Plain Old Telephone Service
PSTN	Public Switched Telecommunication Network
PTN	Public Telephone Network
USGS	United States Geological Survey
VRLA	Valve Regulated Lead-Acid